US007627388B2

(12) **United States Patent**
August et al.

(10) **Patent No.: US 7,627,388 B2**
(45) **Date of Patent: Dec. 1, 2009**

(54) **RELIABILITY TOOLS FOR COMPLEX SYSTEMS**

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(73) Assignee: **Core, Inc.**, Arvada, CO (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 141 days.

(21) Appl. No.: **11/461,316**

(22) Filed: **Jul. 31, 2006**

(65) **Prior Publication Data**

US 2007/0100584 A1 May 3, 2007

Related U.S. Application Data

(60) Provisional application No. 60/731,324, filed on Oct. 28, 2005.

(51) **Int. Cl.**
G05B 9/02 (2006.01)

(52) **U.S. Cl.** **700/79**; 702/185

(58) **Field of Classification Search** 702/184, 702/185; 700/21, 79; 703/6, 7

See application file for complete search history.

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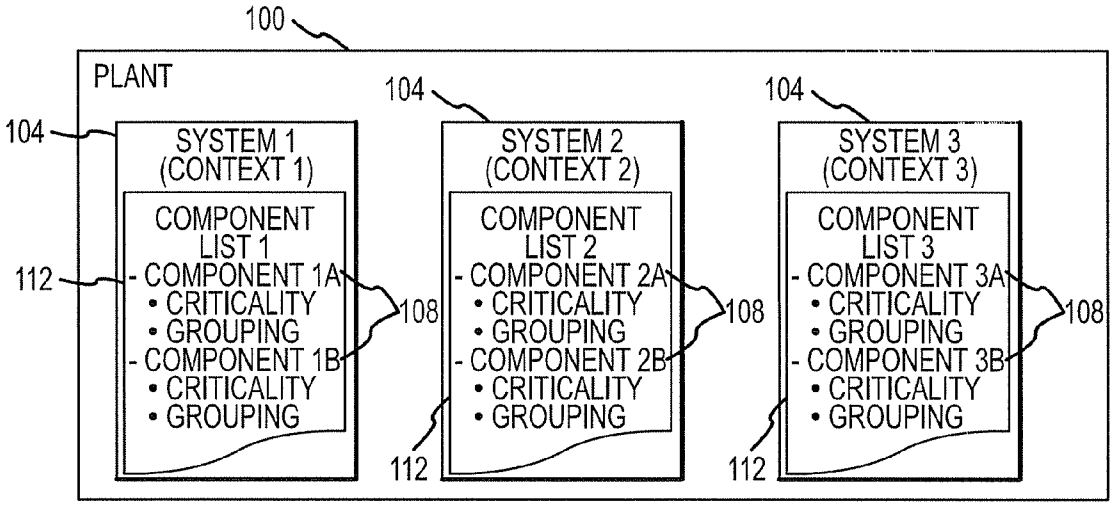
(Continued)

Primary Examiner—Ryan A Jarrett
(74) *Attorney, Agent, or Firm*—Sheridan Ross P.C.

(57) **ABSTRACT**

Tools for the maintenance of complex plants or systems are provided. A master equipment list of components included in a complex plant are organized according to systems. Those components that are critical to the function of the associated system are identified. A template modeling aspects of each critical component is prepared. Information included in applied templates can be reused in association with common or similar components. Particular information included in applied templates may include information related to critical parts within the component, and information regarding maintenance requirements and procedures associated with the component or parts included in the component.

16 Claims, 50 Drawing Sheets



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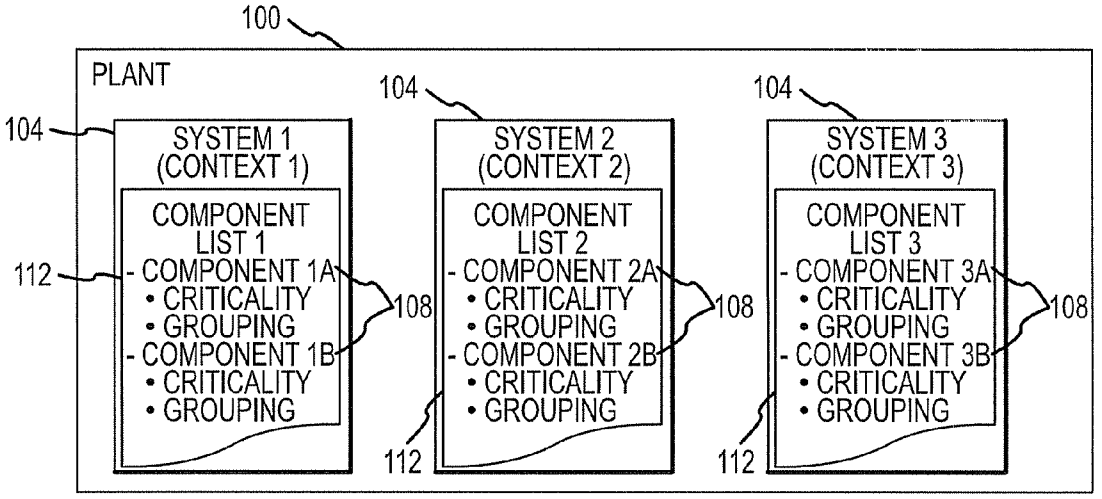
100
PLANT
104
SYSTEM 1
(CONTEXT 1)
COMPONENT
LIST 1
112
- COMPONENT 1A
• CRITICALITY
• GROUPING
- COMPONENT 1B
• CRITICALITY
• GROUPING
108
104
SYSTEM 2
(CONTEXT 2)
COMPONENT
LIST 2
- COMPONENT 2A
• CRITICALITY
• GROUPING
- COMPONENT 2B
• CRITICALITY
• GROUPING
108
112
104
SYSTEM 3
(CONTEXT 3)
COMPONENT
LIST 3
- COMPONENT 3A
• CRITICALITY
• GROUPING
- COMPONENT 3B
• CRITICALITY
• GROUPING
108
112

FIG.1

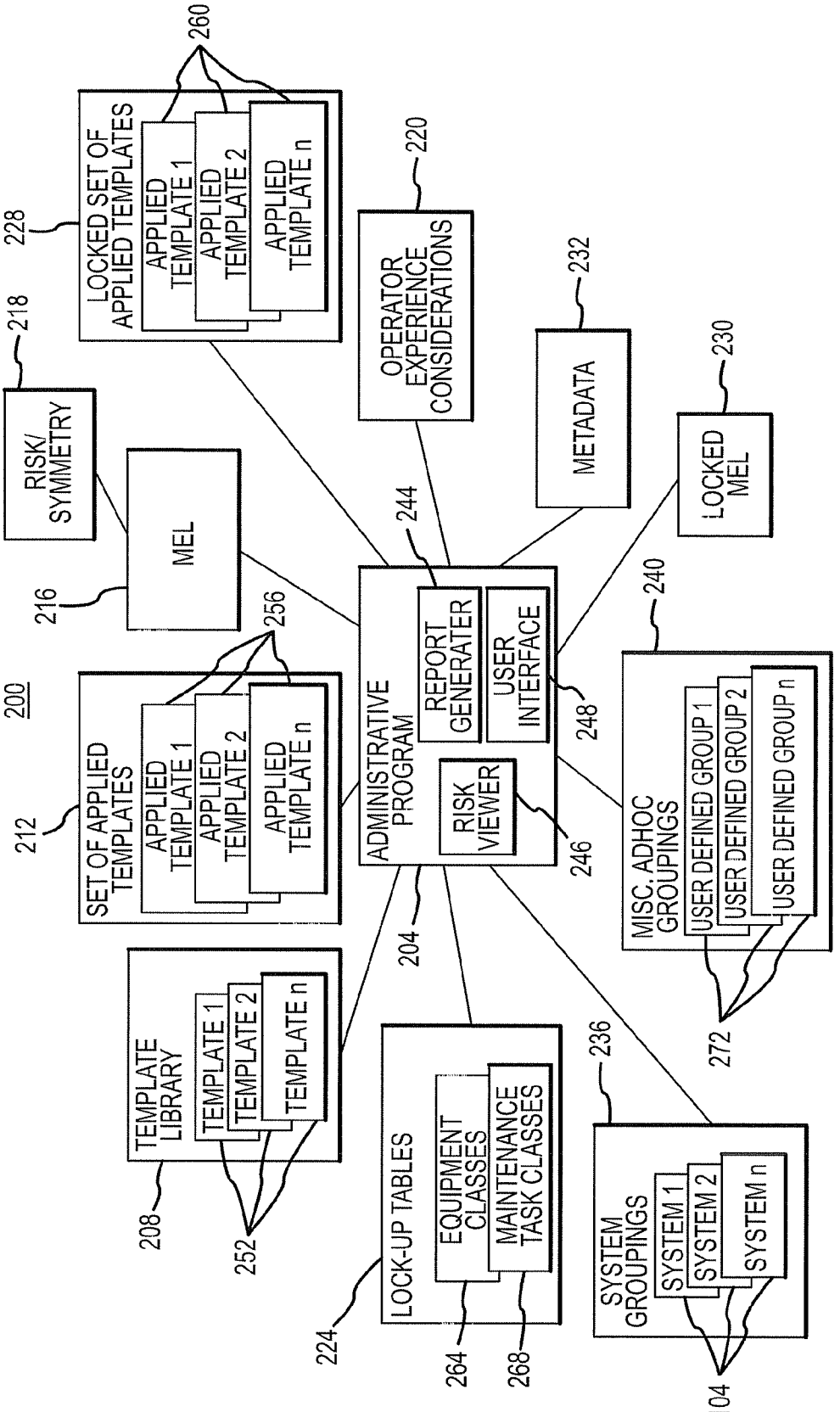
200
ADMINISTRATIVE PROGRAM
REPORT GENERATER
USER INTERFACE
RISK VIEWER
244
246
248
LOCKED SET OF APPLIED TEMPLATES
228
260
APPLIED TEMPLATE 1
APPLIED TEMPLATE 2
APPLIED TEMPLATE n
SET OF APPLIED TEMPLATES
212
256
APPLIED TEMPLATE 1
APPLIED TEMPLATE 2
APPLIED TEMPLATE n
RISK/ SYMMETRY
218
MEL
216
OPERATOR EXPERIENCE CONSIDERATIONS
220
METADATA
232
LOCKED MEL
230
MISC. ADHOC GROUPINGS
240
USER DEFINED GROUP 1
USER DEFINED GROUP 2
USER DEFINED GROUP n
272
TEMPLATE LIBRARY
208
TEMPLATE 1
TEMPLATE 2
TEMPLATE n
252
204
LOCK-UP TABLES
224
EQUIPMENT CLASSES
264
MAINTENANCE TASK CLASSES
268
SYSTEM GROUPINGS
236
SYSTEM 1
SYSTEM 2
SYSTEM n
104

FIG.2

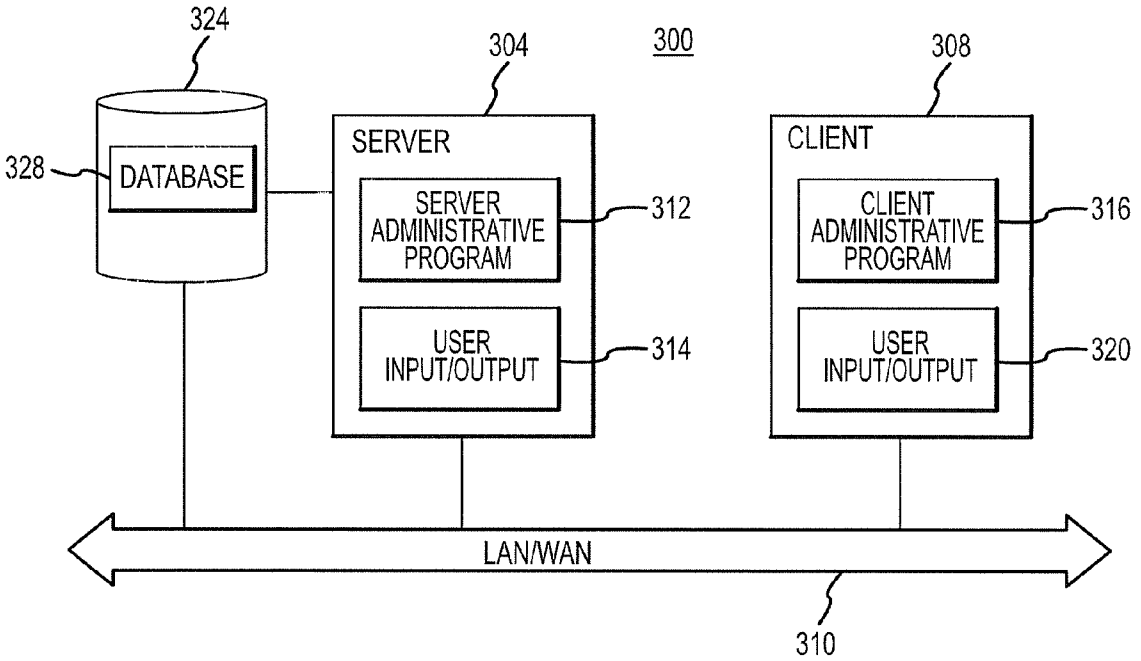
324
304
300
308
328
DATABASE
SERVER
SERVER ADMINISTRATIVE PROGRAM
312
USER INPUT/OUTPUT
314
CLIENT
CLIENT ADMINISTRATIVE PROGRAM
316
USER INPUT/OUTPUT
320
LAN/WAN
310

FIG.3

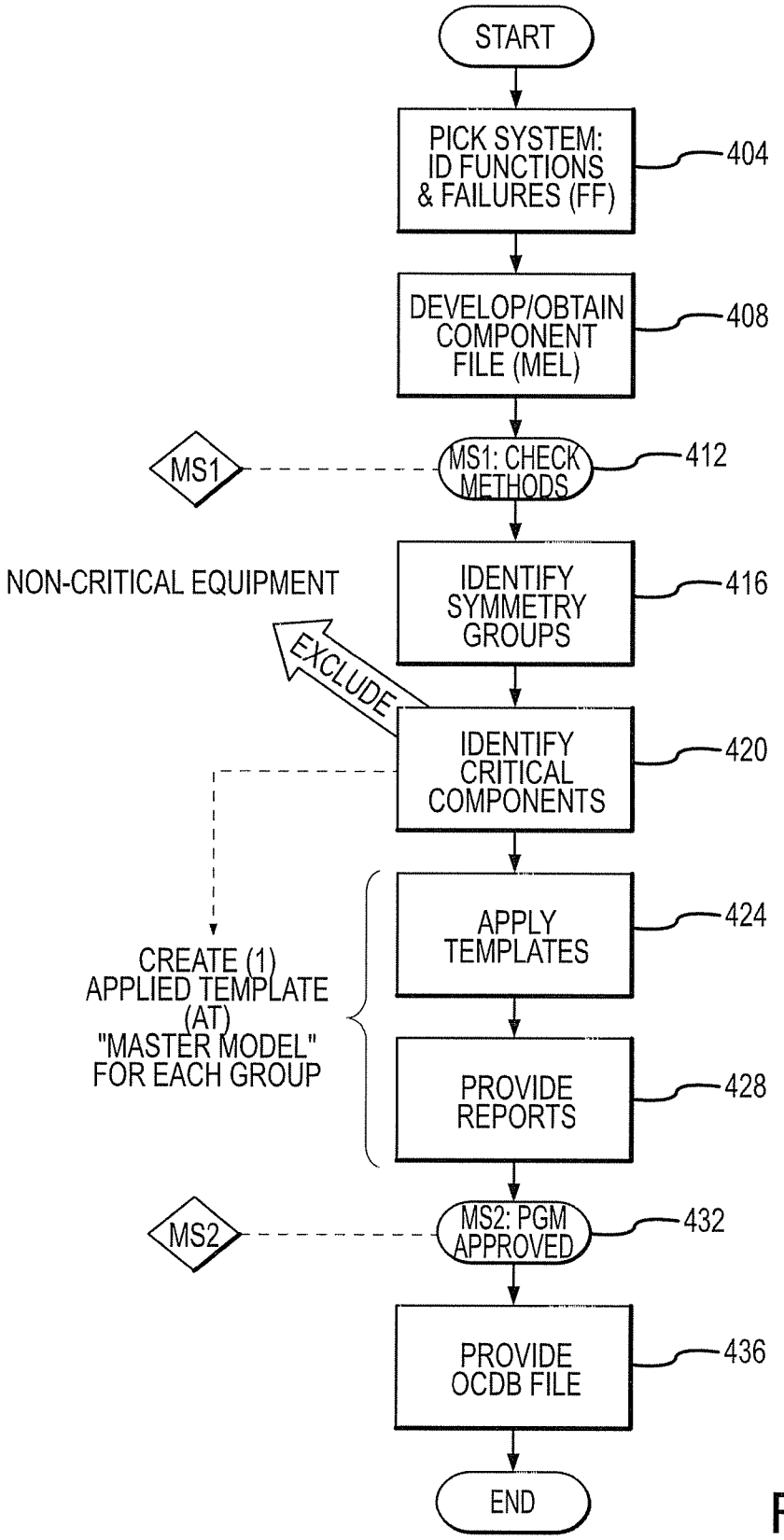
START
PICK SYSTEM: ID FUNCTIONS & FAILURES (FF)
404
DEVELOP/OBTAIN COMPONENT FILE (MEL)
408
MS1
MS1: CHECK METHODS
412
NON-CRITICAL EQUIPMENT
IDENTIFY SYMMETRY GROUPS
416
EXCLUDE
IDENTIFY CRITICAL COMPONENTS
420
CREATE (1) APPLIED TEMPLATE (AT) "MASTER MODEL" FOR EACH GROUP
APPLY TEMPLATES
424
PROVIDE REPORTS
428
MS2
MS2: PGM APPROVED
432
PROVIDE OCDB FILE
436
END

FIG.4

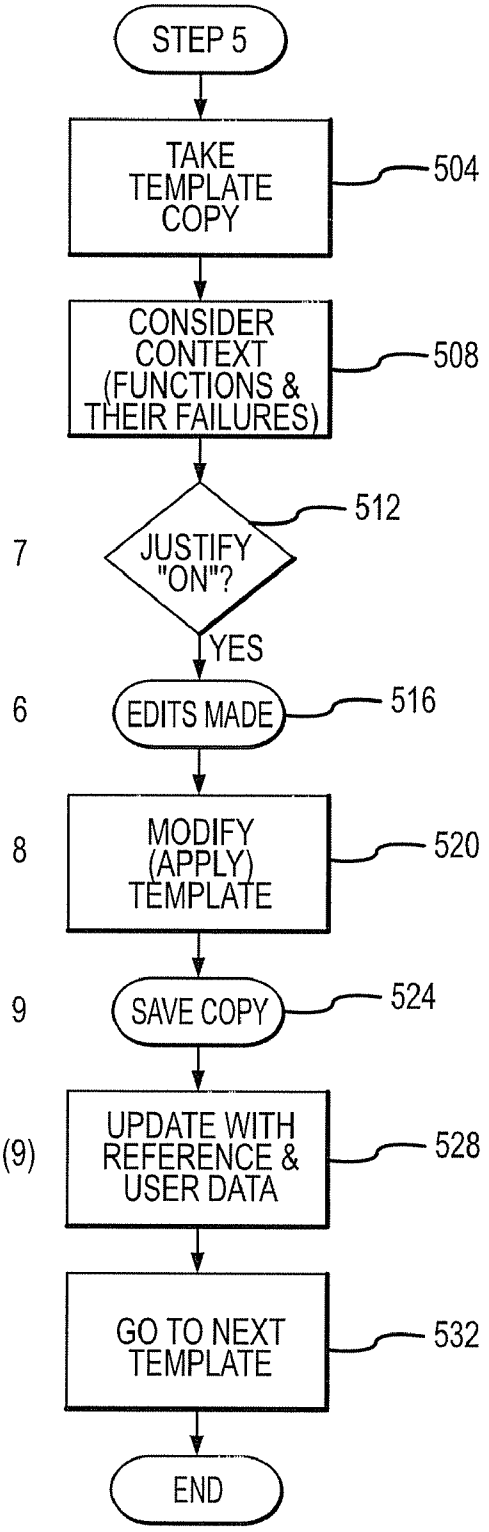
STEP 5
TAKE TEMPLATE COPY
504
CONSIDER CONTEXT (FUNCTIONS & THEIR FAILURES)
508
7
JUSTIFY "ON"?
512
YES
6
EDITS MADE
516
8
MODIFY (APPLY) TEMPLATE
520
9
SAVE COPY
524
(9)
UPDATE WITH REFERENCE & USER DATA
528
GO TO NEXT TEMPLATE
532
END

FIG.5

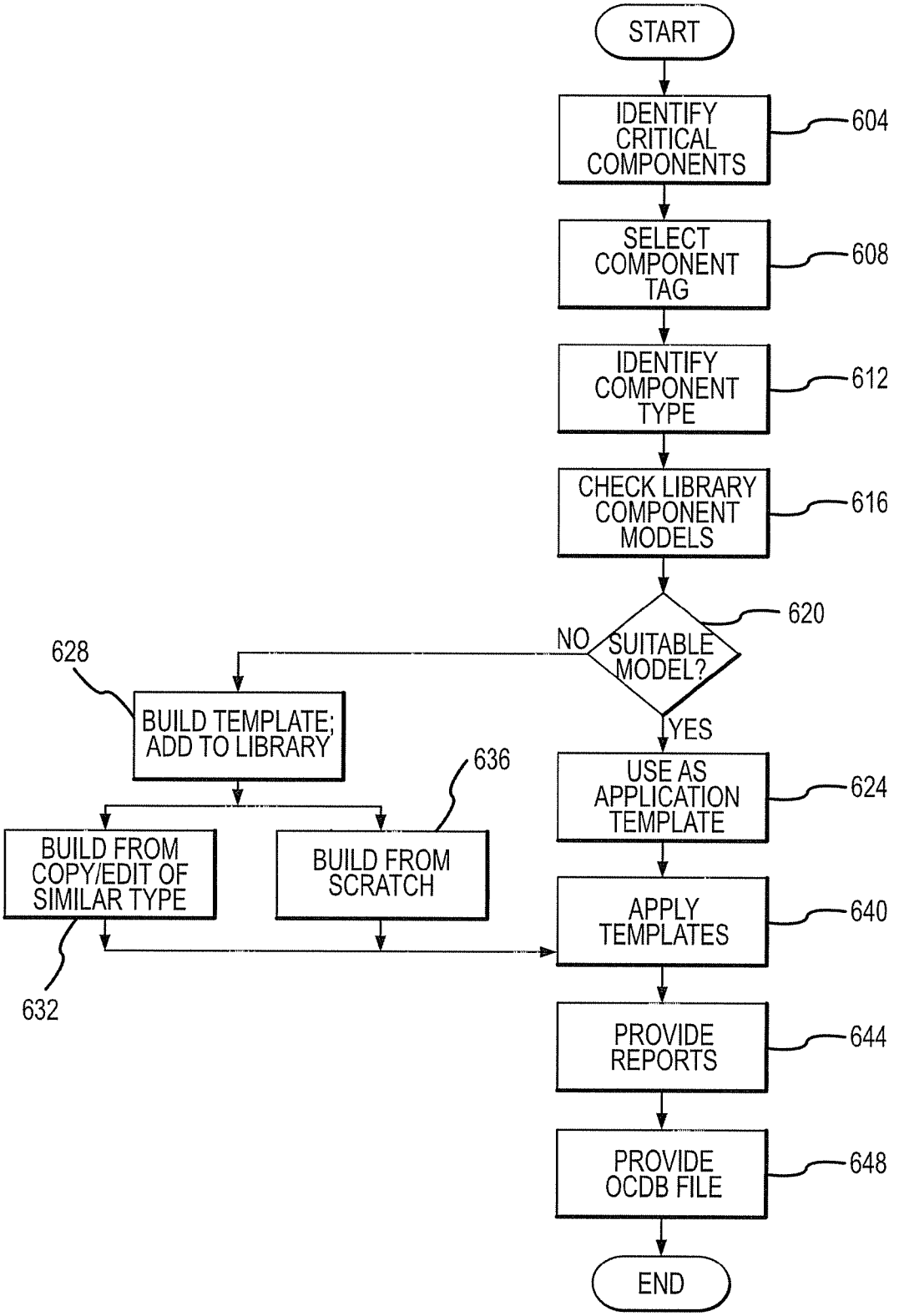
START
IDENTIFY CRITICAL COMPONENTS
604
SELECT COMPONENT TAG
608
IDENTIFY COMPONENT TYPE
612
CHECK LIBRARY COMPONENT MODELS
616
SUITABLE MODEL?
620
NO
YES
628
BUILD TEMPLATE; ADD TO LIBRARY
636
BUILD FROM COPY/EDIT OF SIMILAR TYPE
BUILD FROM SCRATCH
632
USE AS APPLICATION TEMPLATE
624
APPLY TEMPLATES
640
PROVIDE REPORTS
644
PROVIDE OCDB FILE
648
END

FIG.6

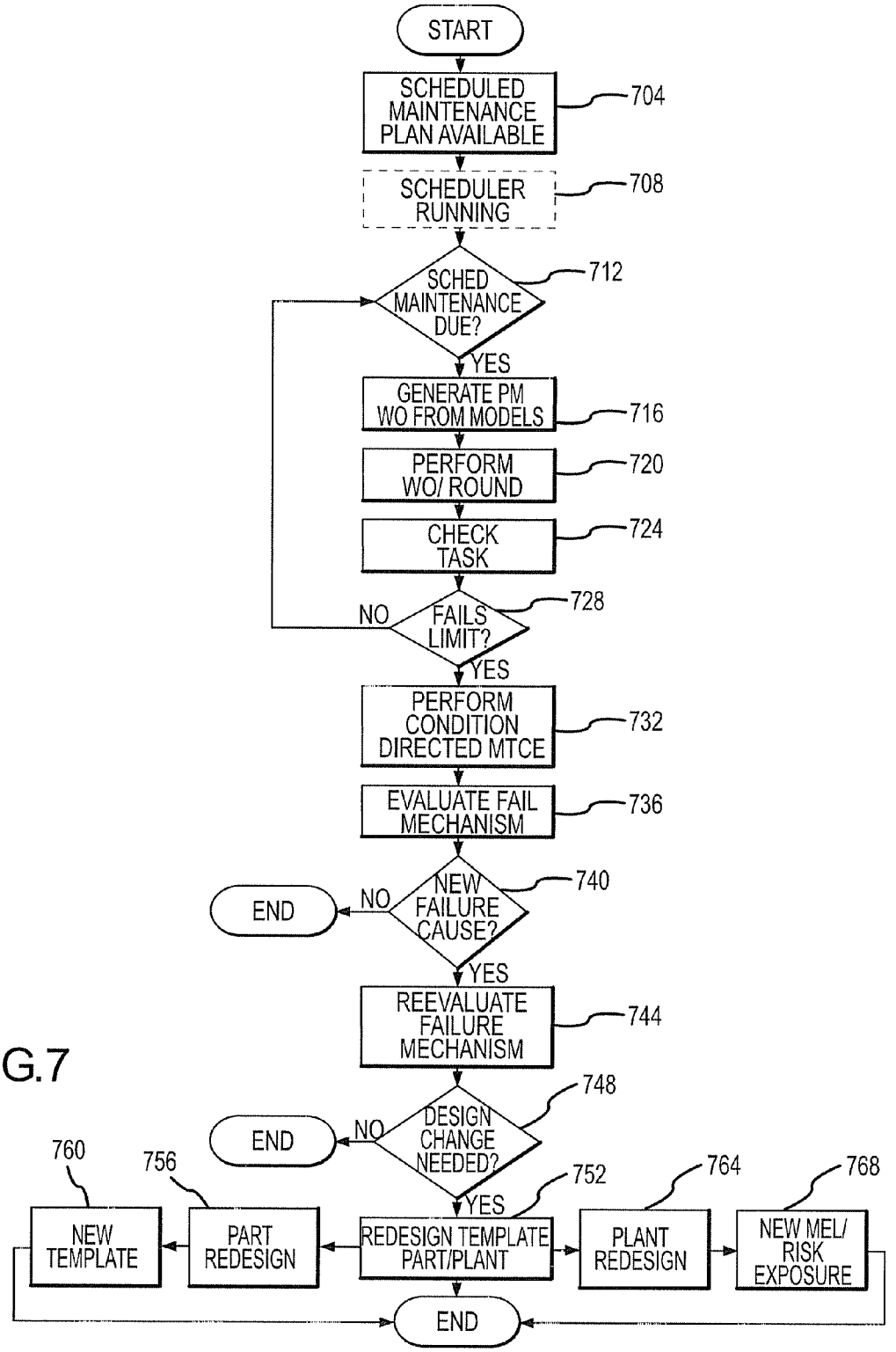
START
SCHEDULED MAINTENANCE PLAN AVAILABLE
704
SCHEDULER RUNNING
708
SCHED MAINTENANCE DUE?
712
YES
GENERATE PM WO FROM MODELS
716
PERFORM WO/ ROUND
720
CHECK TASK
724
NO
FAILS LIMIT?
728
YES
PERFORM CONDITION DIRECTED MTCE
732
EVALUATE FAIL MECHANISM
736
NEW FAILURE CAUSE?
740
END
NO
YES
REEVALUATE FAILURE MECHANISM
744
DESIGN CHANGE NEEDED?
748
END
NO
YES
752
760
756
764
768
NEW TEMPLATE
PART REDESIGN
REDESIGN TEMPLATE PART/PLANT
PLANT REDESIGN
NEW MEL/ RISK EXPOSURE
END

FIG.7

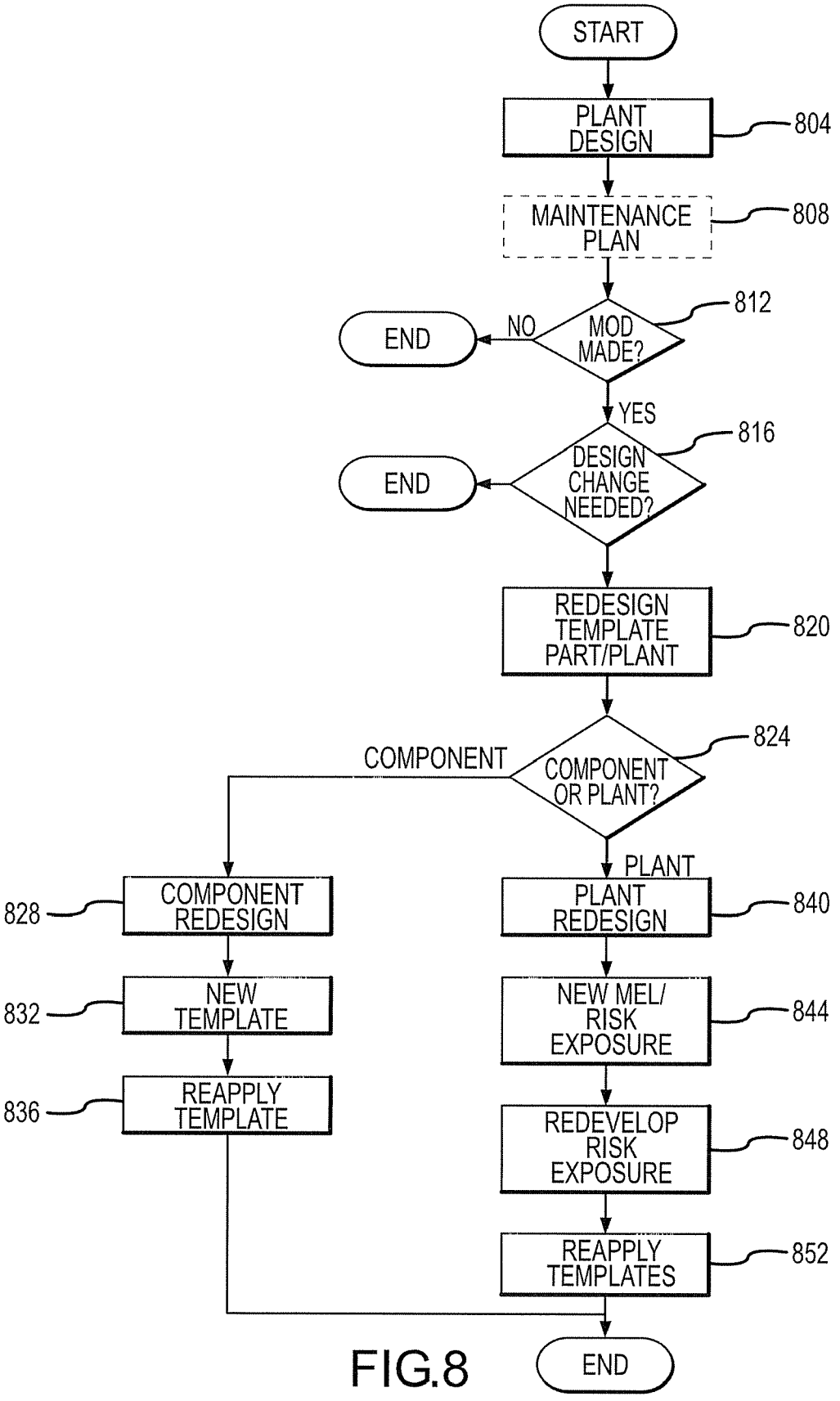
START
PLANT DESIGN
804
MAINTENANCE PLAN
808
MOD MADE?
812
NO
END
YES
DESIGN CHANGE NEEDED?
816
END
REDESIGN TEMPLATE PART/PLANT
820
COMPONENT OR PLANT?
824
COMPONENT
PLANT
COMPONENT REDESIGN
828
NEW TEMPLATE
832
REAPPLY TEMPLATE
836
PLANT REDESIGN
840
NEW MEL/ RISK EXPOSURE
844
REDEVELOP RISK EXPOSURE
848
REAPPLY TEMPLATES
852
END

FIG.8

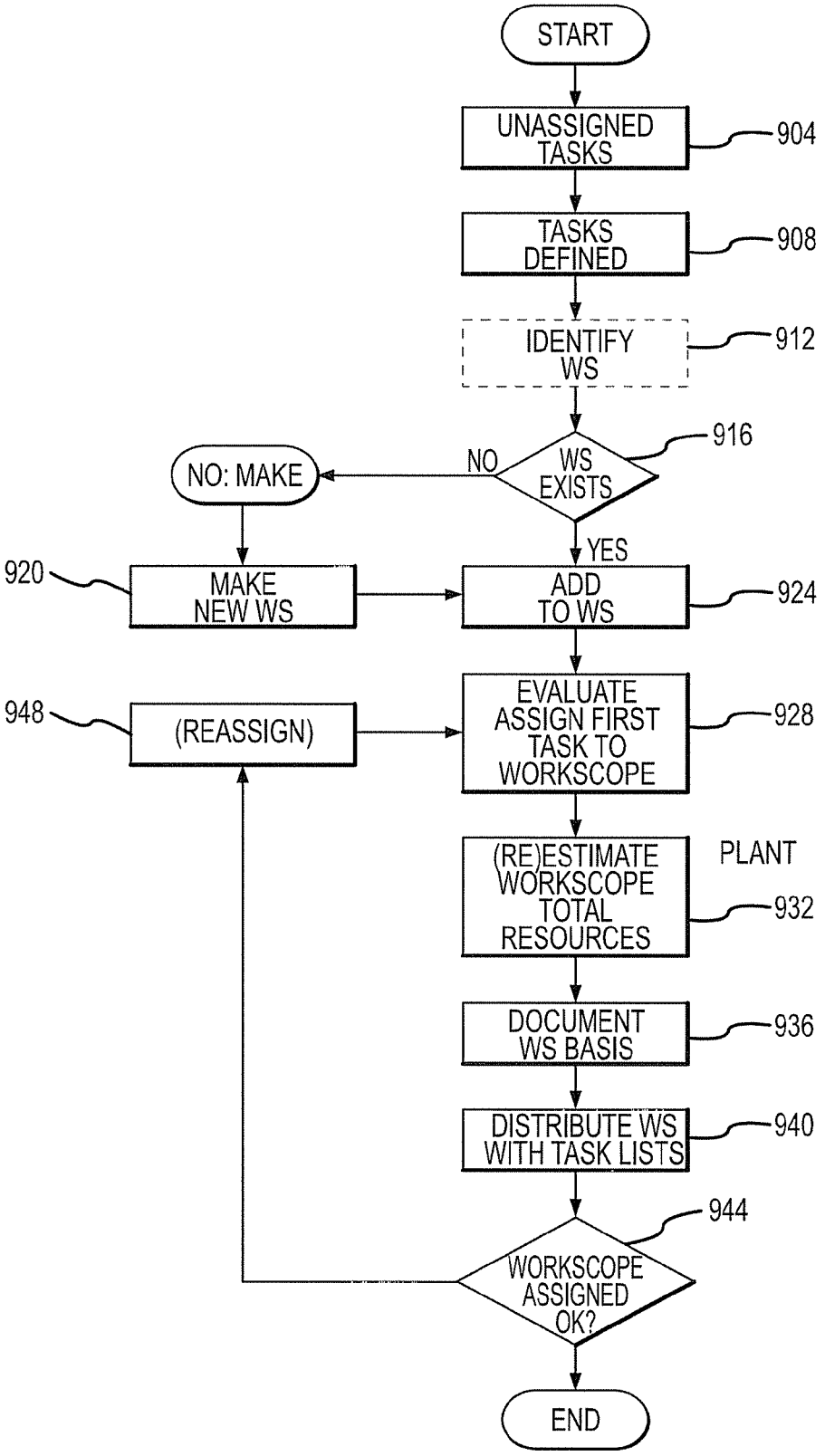
START
UNASSIGNED TASKS
904
TASKS DEFINED
908
IDENTIFY WS
912
916
NO
WS EXISTS
NO: MAKE
YES
920
MAKE NEW WS
ADD TO WS
924
948
(REASSIGN)
EVALUATE ASSIGN FIRST TASK TO WORKSCOPE
928
(RE)ESTIMATE WORKSCOPE TOTAL RESOURCES
PLANT
932
DOCUMENT WS BASIS
936
DISTRIBUTE WS WITH TASK LISTS
940
944
WORKSCOPE ASSIGNED OK?
END

FIG.9

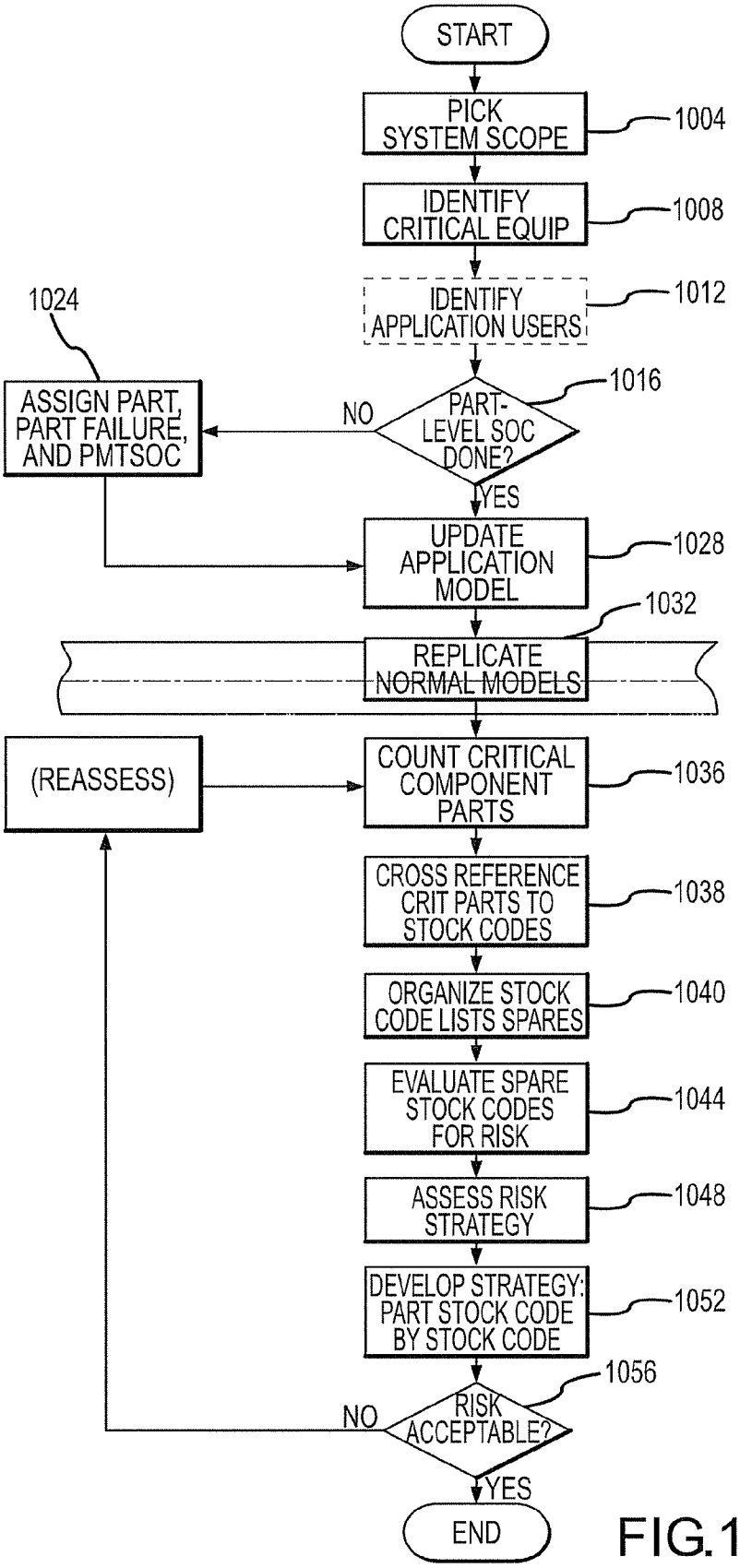
START
PICK SYSTEM SCOPE
1004
IDENTIFY CRITICAL EQUIP
1008
IDENTIFY APPLICATION USERS
1012
1024
ASSIGN PART, PART FAILURE, AND PMTSOC
NO
PART-LEVEL SOC DONE?
1016
YES
UPDATE APPLICATION MODEL
1028
1032
REPLICATE NORMAL MODELS
(REASSESS)
COUNT CRITICAL COMPONENT PARTS
1036
CROSS REFERENCE CRIT PARTS TO STOCK CODES
1038
ORGANIZE STOCK CODE LISTS SPARES
1040
EVALUATE SPARE STOCK CODES FOR RISK
1044
ASSESS RISK STRATEGY
1048
DEVELOP STRATEGY: PART STOCK CODE BY STOCK CODE
1052
1056
NO
RISK ACCEPTABLE?
YES
END

FIG.10

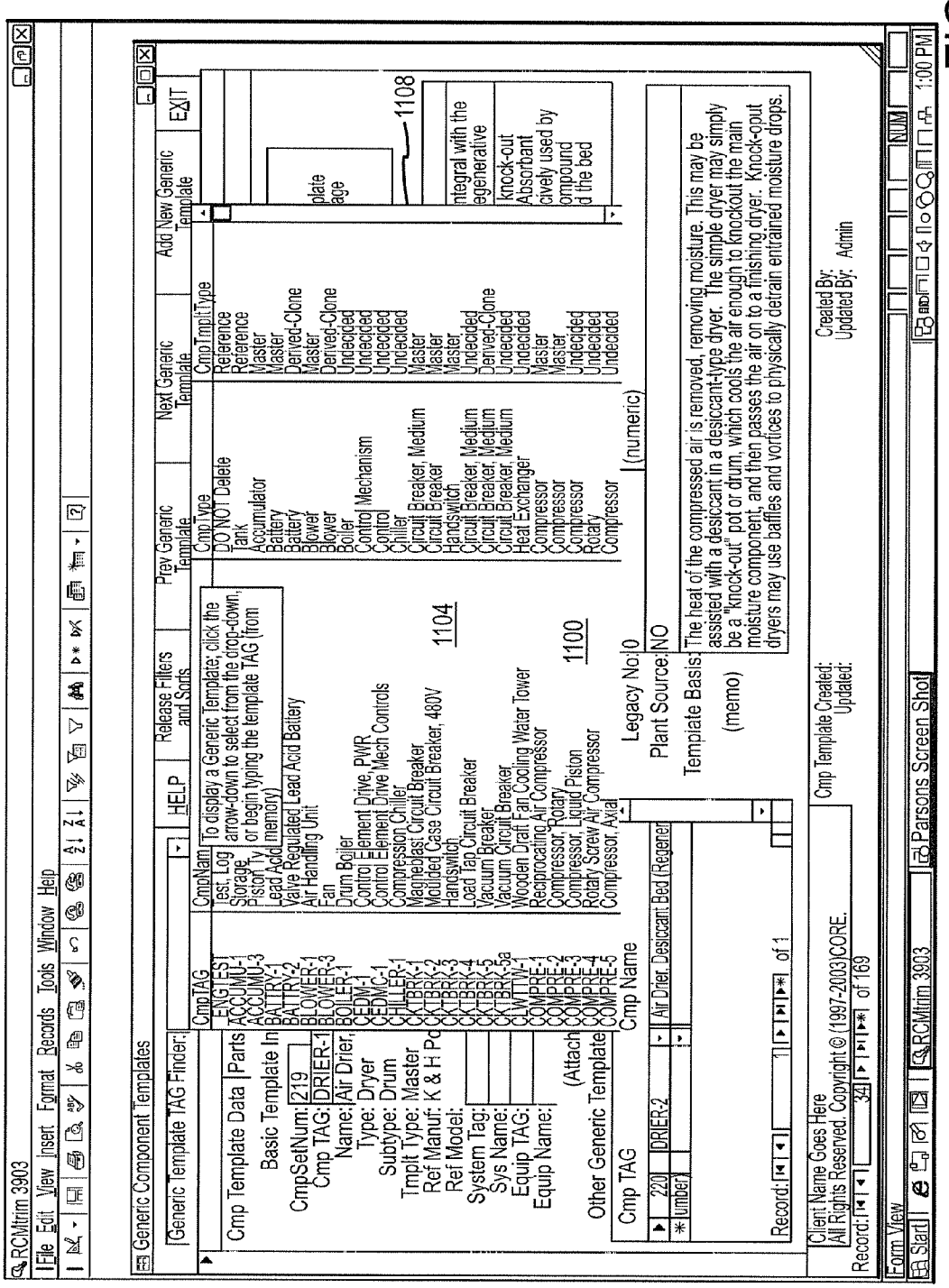
RCMtrim 3903
File Edit View Insert Format Records Tools Window Help
Generic Component Templates
Generic Template TAG Finder:
HELP
Release Filters and Sorts
Prev Generic Template
Next Generic Template
Add New Generic Template
EXIT
Cmp Template Data
Parts
Basic Template In
CmpSetNum: 219
Cmp TAG: DRIER-1
Name: Air Drier,
Type: Dryer
Subtype: Drum
Tmplt Type: Master
Ref Manuf: K & H Po
Ref Model:
System Tag:
Sys Name:
Equip TAG:
Equip Name:
(Attach
Other Generic Template
Cmp TAG
Cmp Name
Air Drier, Desiccant Bed (Regener
Record: 1 of 1
Client Name Goes Here
All Rights Reserved. Copyright © (1997-2003)CORE.
Record: 34 of 169
Cmp Template Created:
Updated:
Legacy No: 0
Plant Source: NO
Template Basis:
(memo)
The heat of the compressed air is removed, removing moisture. This may be assisted with a desiccant in a desiccant-type dryer. The simple dryer may simply be a "knock-out" pot or drum, which cools the air enough to knockout the main moisture component, and then passes the air on to a finishing dryer. Knock-oput dryers may use baffles and vortices to physically detrain entrained moisture drops.
Created By:
Updated By: Admin
1104
1100
1108
Form View
Start
RCMtrim 3903
Parsons Screen Shot
1:00 PM

FIG.11

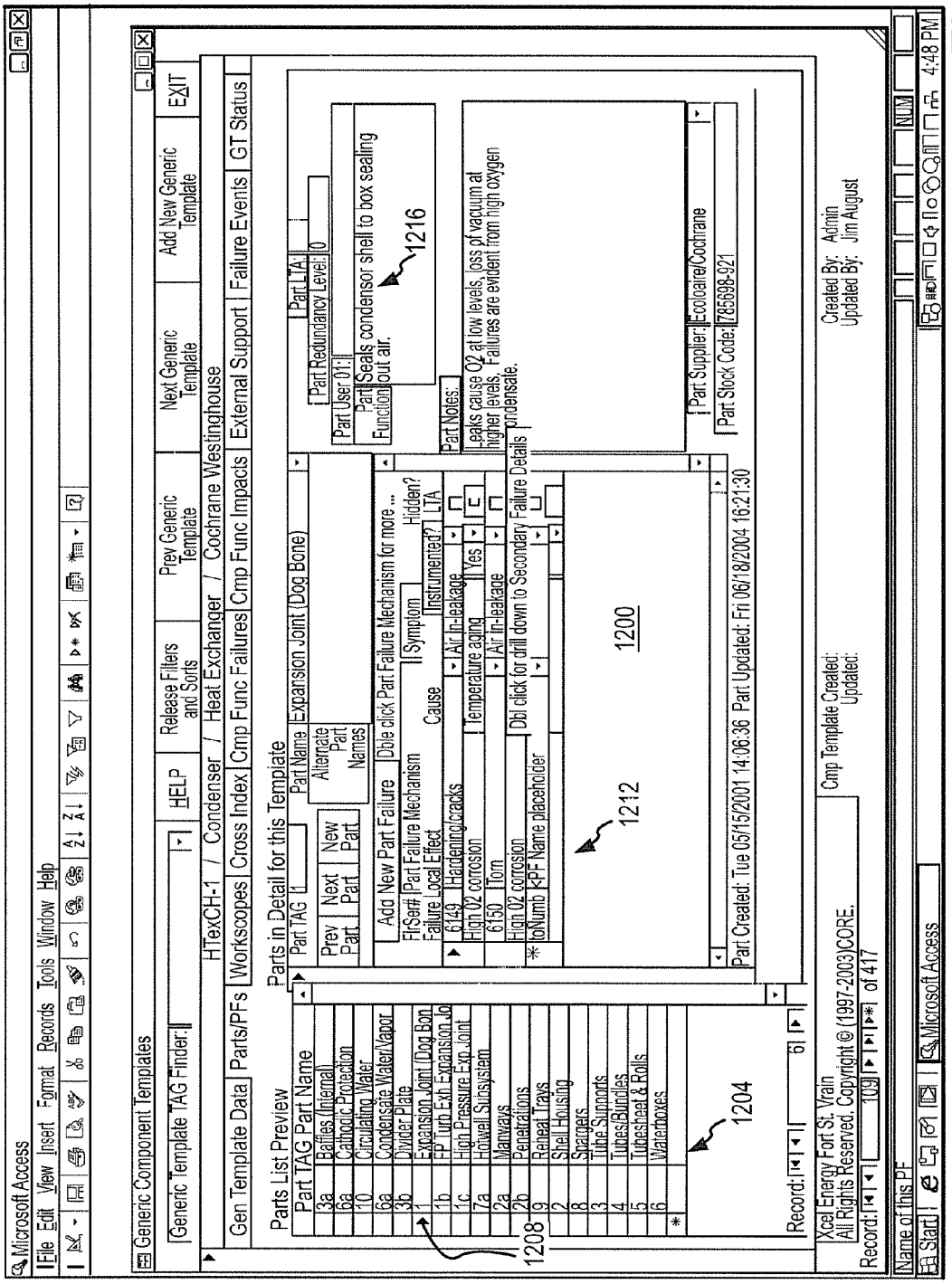
Microsoft Access
File Edit View Insert Format Records Tools Window Help
Generic Component Templates
Generic Template TAG Finder:
HELP
Release Fliters and Softs
Prev Generic Template
Next Generic Template
Add New Generic Template
EXIT
HTexCH-1 / Condenser / Heat Exchanger / Cochrane Westinghouse
Gen Template Data
Parts/PFs
Worksopes
Cross Index
Cmp Func Failures
Cmp Func Impacts
External Support
Failure Events
GT Status
Parts List Preview
Part TAG
Part Name
Parts in Detail for this Template
Expansion Joint (Dog Bone)
Alternate Part Names
Prev Part
Next Part
New Part
Part TAG
Part LTA
Part Redundancy Level: 0
Part User 01:
Part Function: Seals condensor shell to box sealing out air.
1216
Add New Part Failure
Dble click Part Failure Mechanism for more ...
FirSenr
Part Failure Mechanism
Cause
Symptom
Instrumented?
Hidden?
LTA
Failure Local Effect
Part Notes:
Leaks cause O2 at low levels. loss of vacuum at higher levels. Failures are evident from high oxygen condensate.
6149 Hardening/cracks
Air In-leakage
Yes
High 02 corrosion
Temperature aging
6150 Torn
Air In-leakage
High 02 corrosion
Dbl click for drill down to Secondary Failure Details
toNumb
KPF Name placeholder
1212
1200
Part Supplier: Ecolaire/Cochrane
Part Stock Code: 785698-921
Part Created: Tue 05/15/2001 14:06:36 Part Updated: Fri 06/18/2004 16:21:30
Part TAG Part Name
3a Baffles (Internal)
6a Cathodic Protection
10 Circulating Water
6a Condensate Water/Vapor
3b Divider Plate
1 Expansion Joint (Dog Bon
1b FP Turb Exh Expansion Jo
1c High Pressure Exp Joint
7a Hotwell Subsystem
2a Manways
2b Penetrations
9 Reheat Trays
2 Shell Housing
8 Spargers
3 Tube Supports
4 Tubes/Bundles
5 Tubesheet & Rolls
6 Waterboxes
1208
1204
Record: 1 of 417
Cmp Template Created:
Updated:
Created By: Admin
Updated By: Jim August
Xcel Energy Fort St. Vrain
All Rights Reserved. Copyright © (1997-2003)CORE.
Name of this PF
Start
Microsoft Access
NUM
4:48 PM

FIG.12

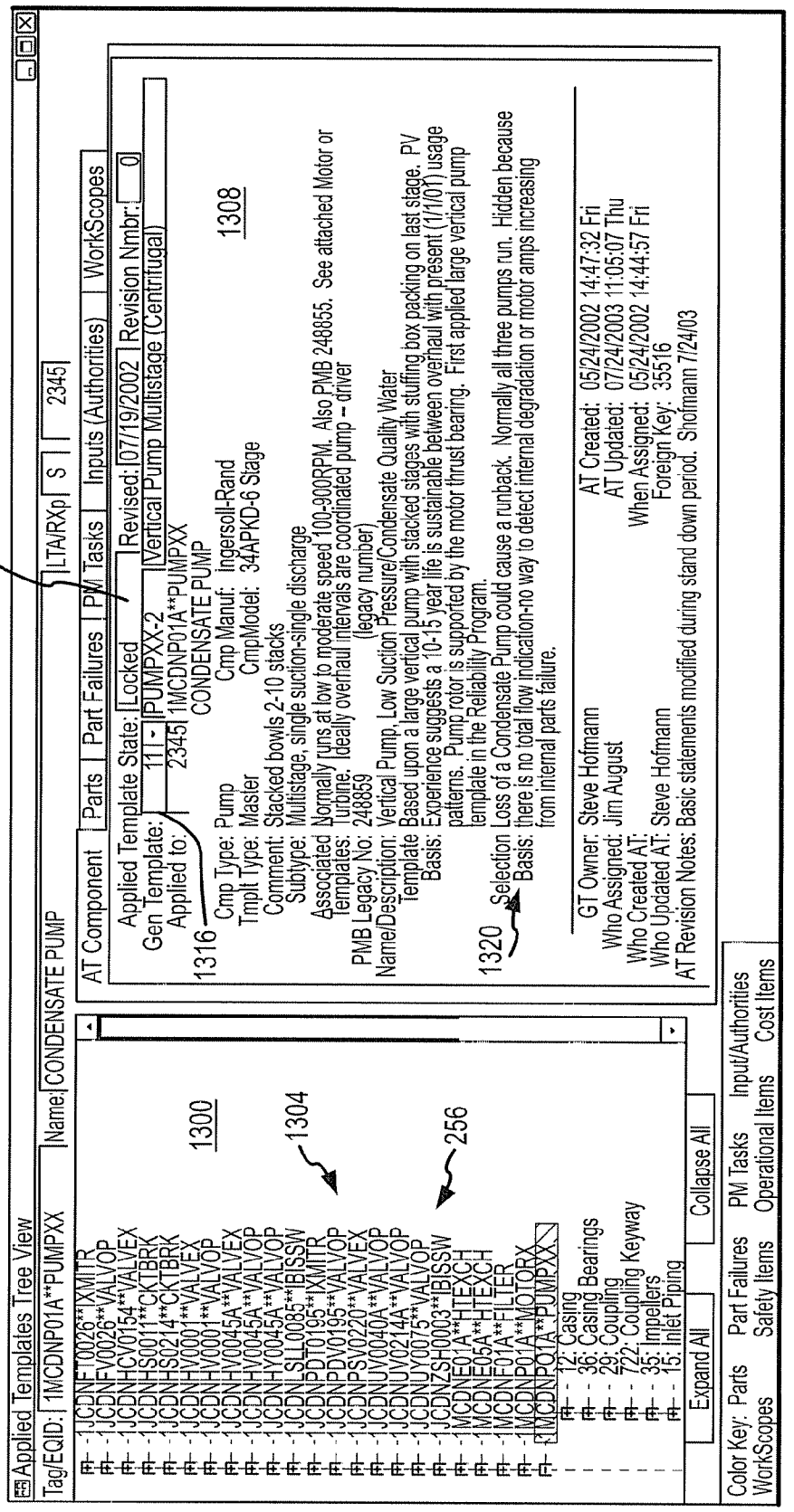
1312
Applied Templates Tree View
Tag/EQID: 1MCDNP01A**PUMPXX
Name: CONDENSATE PUMP
LTA/RXp
S
2345
AT Component
Parts
Part Failures
PM Tasks
Inputs (Authorities)
WorkScopes
Applied Template State: Locked
Revised: 07/19/2002
Revision Nmbr: 0
Gen Template: 111 - PUMPXX-2
Vertical Pump Multistage (Centrifugal)
Applied to: 2345 1MCDNP01A**PUMPXX
CONDENSATE PUMP
1316
Cmp Type: Pump
Cmp Manuf: Ingersoll-Rand
1308
Tmplt Type: Master
CmpModel: 34APKD-6 Stage
Comment: Stacked bowls 2-10 stacks
Subtype: Multistage, single suction-single discharge
Associated Templates: Normally runs at low to moderate speed 100-900RPM. Also PMB 248855. See attached Motor or Turbine. Ideally overhaul intervals are coordinated pump – driver
PMB Legacy No: 248859 (legacy number)
Name/Description: Vertical Pump, Low Suction Pressure/Condensate Quality Water
Template Basis: Based upon a large vertical pump with stacked stages with stuffing box packing on last stage. PV Experience suggests a 10-15 year life is sustainable between overhaul with present (1/1/01) usage patterns. Pump rotor is supported by the motor thrust bearing. First applied large vertical pump template in the Reliability Program.
1320
Selection Basis: Loss of a Condensate Pump could cause a runback. Normally all three pumps run. Hidden because there is no total flow indication-no way to detect internal degradation or motor amps increasing from internal parts failure.
GT Owner: Steve Hofmann
AT Created: 05/24/2002 14:47:32 Fri
Who Assigned: Jim August
AT Updated: 07/24/2003 11:05:07 Thu
Who Created AT:
When Assigned: 05/24/2002 14:44:57 Fri
Who Updated AT: Steve Hofmann
Foreign Key: 35516
AT Revision Notes: Basic statements modified during stand down period. Shofmann 7/24/03
1300
1304
256
1JCDNFT0026**IXMITR
1JCDNFV0026**VALVOP
1JCDNHCV0154**VALVEX
1JCDNHS0011**CKTBRK
1JCDNHS0214**CKTBRK
1JCDNHV0001**VALVEX
1JCDNHV0001**VALVOP
1JCDNHV0045A**VALVEX
1JCDNHV0045A**VALVOP
1JCDNHY0045A**VALVOP
1JCDNLSLL0085**BISSW
1JCDNPDT0195**IXMITR
1JCDNPDV0195**VALVOP
1JCDNPSV0220**VALVEX
1JCDNUV0040A**VALVOP
1JCDNUV0214A**VALVOP
1JCDNUY0075**VALVOP
1JCDNZSH0003**BISSW
1MCDNE01A**HTEXCH
1MCDNE05A**HTEXCH
1MCDNF01A**FILTER
1MCDNP01A**MOTORX
1MCDNP01A**PUMPXX
12: Casing
36: Casing Bearings
29: Coupling
722: Coupling Keyway
35: Impellers
15: Inlet Piping
Expand All
Collapse All
Color Key: Parts
Part Failures
PM Tasks
Input/Authorities
WorkScopes
Safety Items
Operational Items
Cost Items

FIG.13

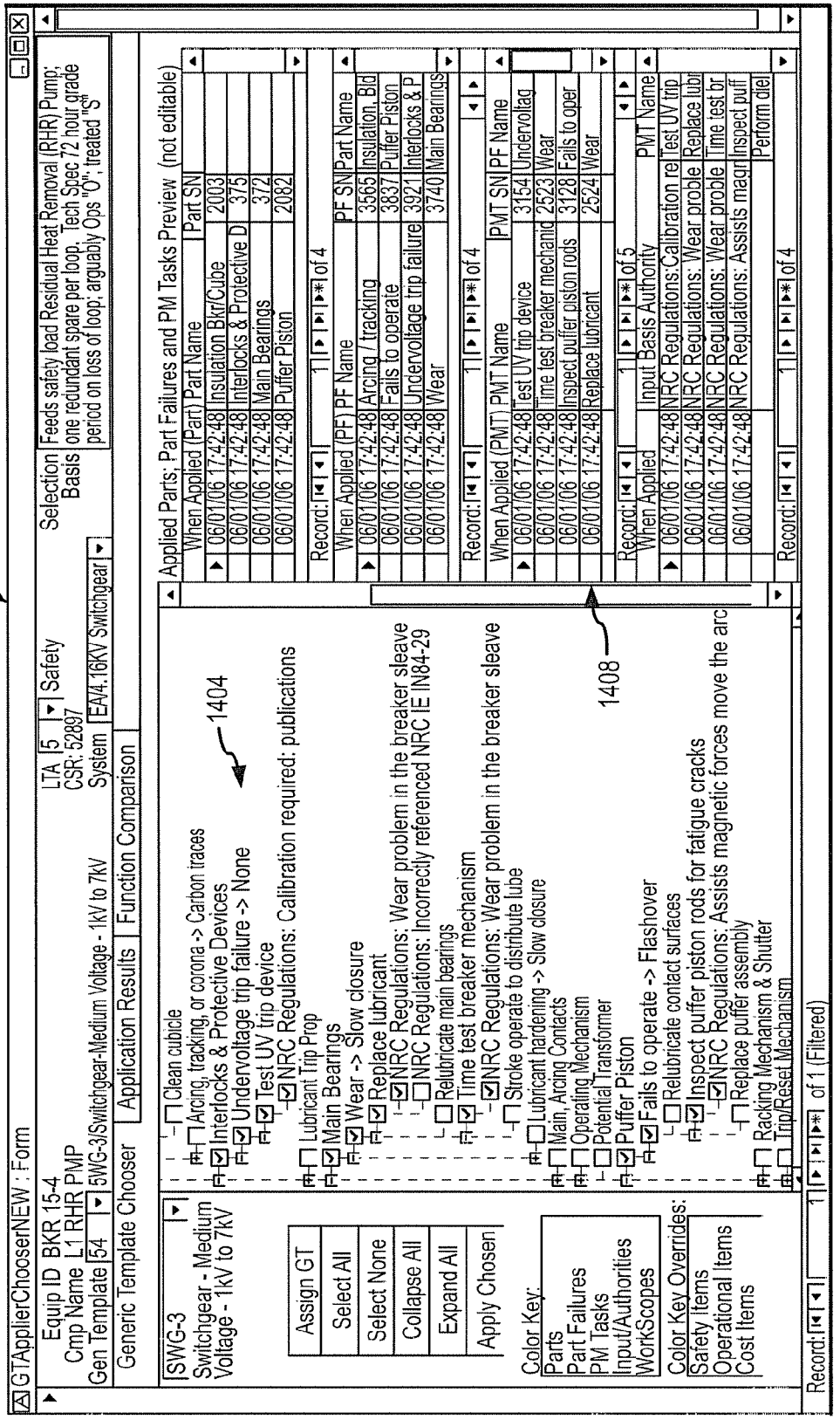
1400
GTApplierChooserNEW : Form
Equip ID BKR 15-4
Cmp Name L1 RHR PMP
Gen Template 54
5WG-3/Switchgear-Medium Voltage - 1kV to 7kV
LTA 5
CSR: 52897
System EA/4.16KV Switchgear
Selection Basis
Feeds safety load Residual Heat Removal (RHR) Pump; one redundant spare per loop, Tech Spec 72 hour grade period on loss of loop; arguably Ops "O"; treated "S"
Generic Template Chooser
Application Results
Function Comparison
SWG-3
Switchgear - Medium Voltage - 1kV to 7kV
Assign GT
Select All
Select None
Collapse All
Expand All
Apply Chosen
Color Key:
Parts
Part Failures
PM Tasks
Input/Authorities
WorkScopes
Color Key Overrides:
Safety Items
Operational Items
Cost Items
Clean cubicle
Arcing, tracking, or corona -> Carbon traces
Interlocks & Protective Devices
Undervoltage trip failure -> None
Test UV trip device
NRC Regulations: Calibration required: publications
Lubricant Trip Prop
Main Bearings
Wear -> Slow closure
Replace lubricant
NRC Regulations: Wear problem in the breaker sleave
NRC Regulations: Incorrectly referenced NRC IE IN84-29
Relubricate main bearings
Time test breaker mechanism
NRC Regulations: Wear problem in the breaker sleave
Stroke operate to distribute lube
Lubricant hardening -> Slow closure
Main, Arcing Contacts
Operating Mechanism
Potential Transformer
Puffer Piston
Fails to operate -> Flashover
Relubricate contact surfaces
Inspect puffer piston rods for fatigue cracks
NRC Regulations: Assists magnetic forces move the arc
Replace puffer assembly
Racking Mechanism & Shutter
Trip/Reset Mechanism
1404
1408
Applied Parts; Part Failures and PM Tasks Preview (not editable)
When Applied (Part) | Part | Part SN
06/01/06 17:42:48 | Insulation Bkr/Cube | 2003
06/01/06 17:42:48 | Interlocks & Protective D | 375
06/01/06 17:42:48 | Main Bearings | 372
06/01/06 17:42:48 | Puffer Piston | 2082
When Applied (PF) | PF Name | PF SN | Part Name
06/01/06 17:42:48 | Arcing / tracking | 3565 | Insulation, Bld
06/01/06 17:42:48 | Fails to operate | 3837 | Puffer Piston
06/01/06 17:42:48 | Undervoltage trip failure | 3921 | Interlocks & P
06/01/06 17:42:48 | Wear | 3740 | Main Bearings
When Applied (PMT) | PMT Name | PMT SN | PF Name
06/01/06 17:42:48 | Test UV trip device | 3154 | Undervoltag
06/01/06 17:42:48 | Time test breaker mechanis | 2523 | Wear
06/01/06 17:42:48 | Inspect puffer piston rods | 3128 | Fails to oper
06/01/06 17:42:48 | Replace lubricant | 2524 | Wear
When Applied | Input Basis Authority | PMT Name
06/01/06 17:42:48 | NRC Regulations:Calibration re | Test UV trip
06/01/06 17:42:48 | NRC Regulations: Wear proble | Replace lubri
06/01/06 17:42:48 | NRC Regulations: Wear proble | Time test br
06/01/06 17:42:48 | NRC Regulations: Assists magn | Inspect puff
Perform diel
Record: 1 of 1 (Filtered)

FIG.14

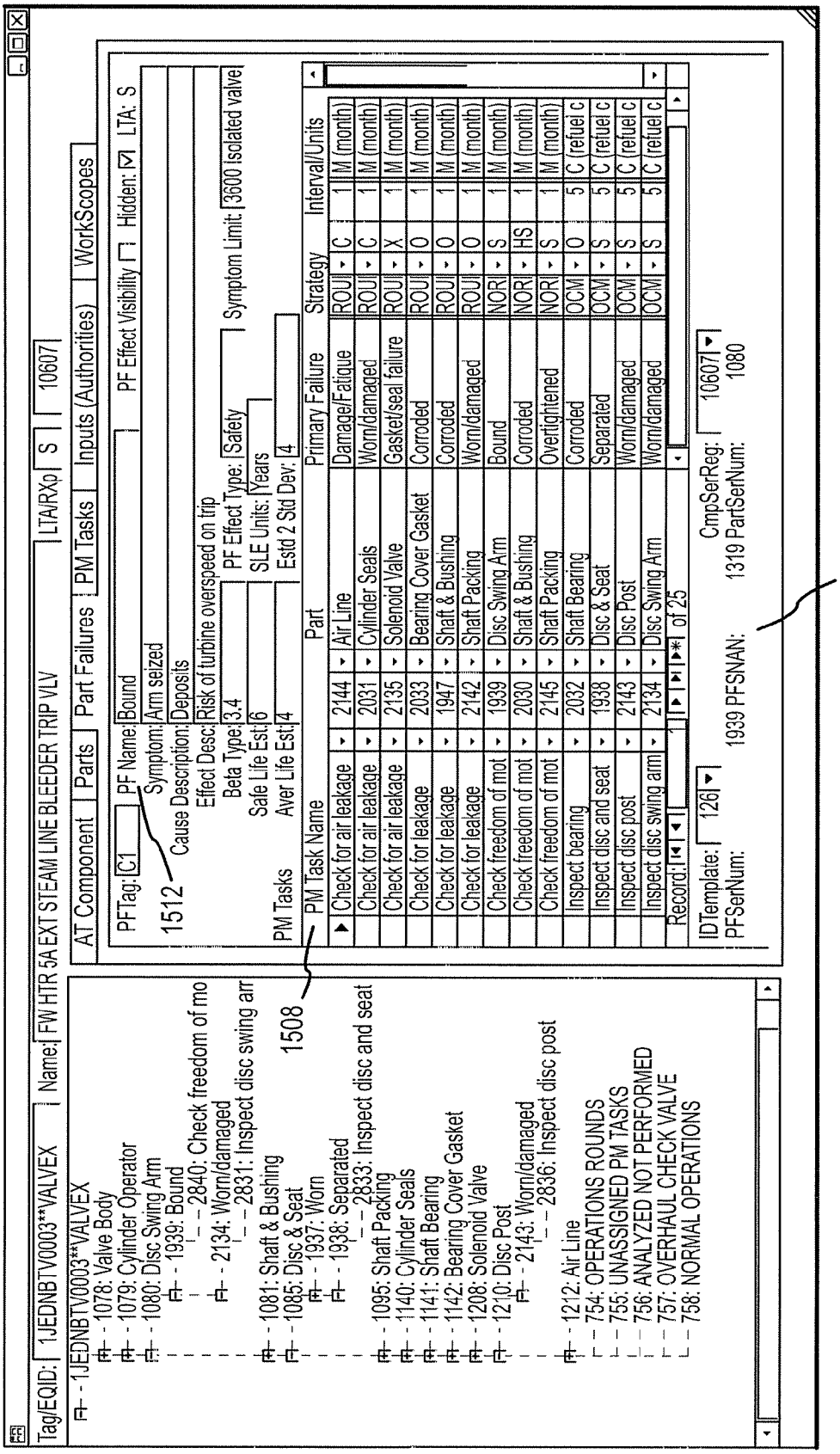
Tag/EQID: 1JEDNBTV0003**VALVEX
Name: FW HTR 5A EXT STEAM LINE BLEEDER TRIP VLV
LTA/RXp
S
10607
AT Component
Parts
Part Failures
PM Tasks
Inputs (Authorities)
WorkScopes
1JEDNBTV0003**VALVEX
1078: Valve Body
1079: Cylinder Operator
1080: Disc Swing Arm
1939: Bound
2840: Check freedom of mo
2134: Worn/damaged
2831: Inspect disc swing arr
1081: Shaft & Bushing
1085: Disc & Seat
1937: Worn
1938: Separated
2833: Inspect disc and seat
1095: Shaft Packing
1140: Cylinder Seals
1141: Shaft Bearing
1142: Bearing Cover Gasket
1208: Solenoid Valve
1210: Disc Post
2143: Worn/damaged
2836: Inspect disc post
1212: Air Line
754: OPERATIONS ROUNDS
755: UNASSIGNED PM TASKS
756: ANALYZED NOT PERFORMED
757: OVERHAUL CHECK VALVE
758: NORMAL OPERATIONS
1508
PFTag: C1
PF Name: Bound
PF Effect Visibility
Hidden:
LTA: S
1512
Symptom: Arm seized
Cause Description: Deposits
Effect Desc: Risk of turbine overspeed on trip
Beta Type: 3.4
PF Effect Type: Safety
Symptom Limit: 3600 isolated valve
Safe Life Est: 6
SLE Units: Years
PM Tasks
Aver Life Est: 4
Estd 2 Std Dev: 4
PM Task Name
Part
Primary Failure
Strategy
Interval/Units
Check for air leakage 2144 Air Line Damage/Fatigue RCUI C 1 M (month)
Check for air leakage 2031 Cylinder Seals Worn/damaged RCUI C 1 M (month)
Check for air leakage 2135 Solenoid Valve Gasket/seal failure RCUI X 1 M (month)
Check for leakage 2033 Bearing Cover Gasket Corroded RCUI O 1 M (month)
Check for leakage 1947 Shaft & Bushing Corroded RCUI O 1 M (month)
Check for leakage 2142 Shaft Packing Worn/damaged RCUI O 1 M (month)
Check freedom of mot 1939 Disc Swing Arm Bound NORI S 1 M (month)
Check freedom of mot 2030 Shaft & Bushing Corroded NORI HS 1 M (month)
Check freedom of mot 2145 Shaft Packing Overtightened NORI S 1 M (month)
Inspect bearing 2032 Shaft Bearing Corroded OCM O 5 C (refuel c
Inspect disc and seat 1938 Disc & Seat Separated OCM S 5 C (refuel c
Inspect disc post 2143 Disc Post Worn/damaged OCM S 5 C (refuel c
Inspect disc swing arm 2134 Disc Swing Arm Worn/damaged OCM S 5 C (refuel c
Record: 1 of 25
IDTemplate: 126
CmpSerReg: 10607
PFSerNum:
1939 PFSNAN:
1319 PartSerNum: 1080
1504

FIG.15

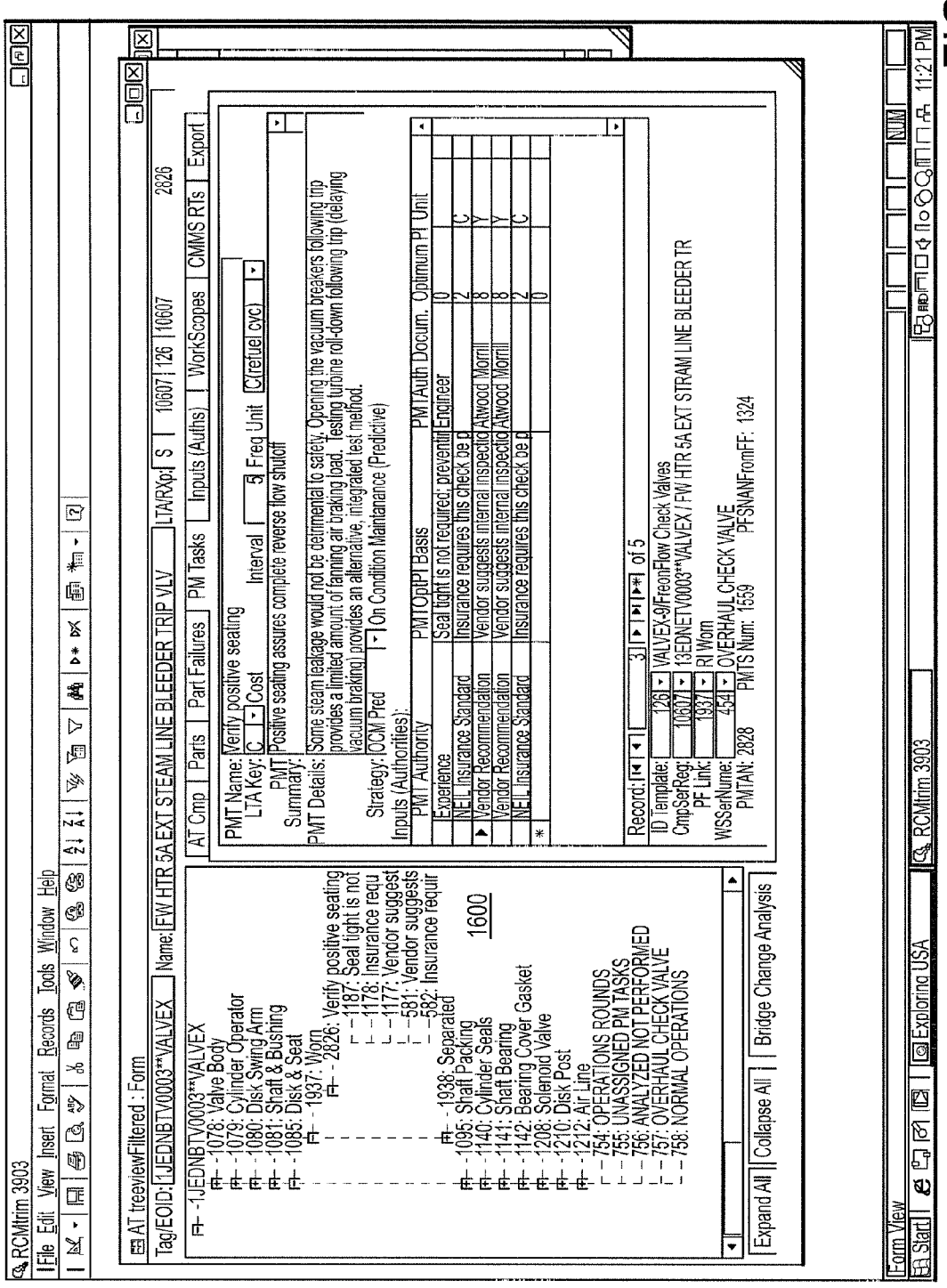
RCMtrim 3903
File Edit View Insert Format Records Tools Window Help
AT treeviewFiltered : Form
Tag/EOID: 1JEDNBTV0003**VALVEX
Name: FW HTR 5A EXT STEAM LINE BLEEDER TRIP VLV
LTA/RXpf S 10607 126 10607
2826
1JEDNBTV0003**VALVEX
1078: Valve Body
1079: Cylinder Operator
1080: Disk Swing Arm
1081: Shaft & Bushing
1085: Disk & Seat
1937: Worm
2826: Verify positive seating
1187: Seal tight is not
1178: Insurance requ
1177: Vendor suggest
581: Vendor suggests
582: Insurance requir
1938: Separated
1095: Shaft Packing
1140: Cylinder Seals
1141: Shaft Bearing
1142: Bearing Cover Gasket
1208: Solenoid Valve
1210: Disk Post
1212: Air Line
754: OPERATIONS ROUNDS
755: UNASSIGNED PM TASKS
756: ANALYZED NOT PERFORMED
757: OVERHAUL CHECK VALVE
758: NORMAL OPERATIONS
1600
Expand All
Collapse All
Bridge Change Analysis
AT Cmp
Parts
Part Failures
PM Tasks
Inputs (Auths)
WorkScopes
CMMS RTs
Export
PMT Name: Verify positive seating
LTA Key: C
Cost
Interval
Freq Unit (Cfretuel cyc)
PMT Summary: Positive seating assures complete reverse flow shutoff
PMT Details: Some steam leakage would not be detrimental to safety. Opening the vacuum breakers following trip provides a limited amount of fanning air braking load. Testing turbine roll-down following trip (delaying vacuum braking) provides an alternative, integrated test method.
Strategy: OCM Pred
On Condition Maintanance (Predictive)
Inputs (Authorities):
PMT Authority
PMTOpPI Basis
PMTAuth Docum.
Optimum PI Unit
Experience
Seal tight is not required; preventi
Engineer
0
NEIL Insurance Standard
Insurance requires this check be p
2
C
Vendor Recommendation
Vendor suggests internal inspectio
Atwood Morrill
8
Y
Vendor Recommendation
Vendor suggests internal inspectio
Atwood Morrill
8
Y
NEIL Insurance Standard
Insurance requires this check be p
2
C
0
Record: 3 of 5
ID Template: 126 VALVEX-9/FreonFlow Check Valves
CmpSerReg: 10607 13EDNETV0003**VALVEX / FW HTR 5A EXT STRAM LINE BLEEDER TR
PF Link: 1937 RI Worn
WSSerNume: 454 OVERHAUL CHECK VALVE
PMTAN: 2828 PMTS Num: 1559 PFSNANFromFF: 1324
Form View
Start
Exploring USA
RCMtrim 3903
NUM
11:21 PM

FIG.16

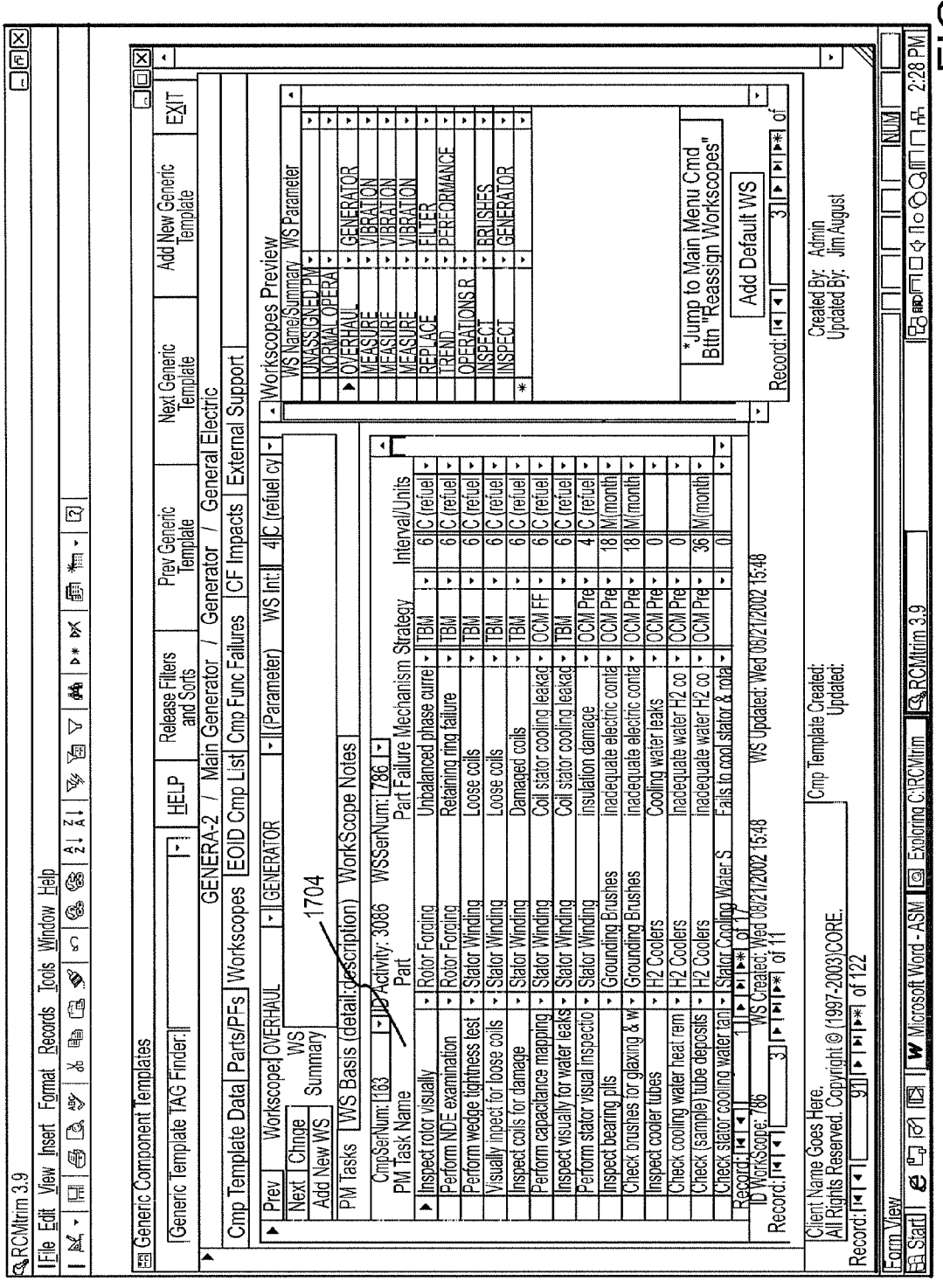
RCMtrim 3.9
File Edit View Insert Format Records Tools Window Help
Generic Component Templates
Generic Template TAG Finder:
HELP
Release Filters and Sorts
Prev Generic Template
Next Generic Template
Add New Generic Template
EXIT
GENERA-2 / Main Generator / Generator / General Electric
Cmp Template Data | Parts/PFs | WorksCopes | EOID Cmp List | Cmp Func Failures | CF Impacts | External Support
Prev
Next
Add New WS
Chnge
WS Summary
Workscope: OVERHAUL
GENERATOR
(Parameter)
WS Int: 4
C (refuel cy
1704
PM Tasks | WS Basis (detail description) | WorkScope Notes
CmpSerNum: 1183
ID Activity: 3086
WSSerNum: 1786
PM Task Name
Part
Failure Mechanism
Strategy
Interval/Units
Inspect rotor visually
Rotor Forcing
Unbalanced phase current
TBM
6
C (refuel
Perform NDE examination
Rotor Forcing
Retaining ring failure
TBM
6
C (refuel
Perform wedge tightness test
Stator Winding
Loose coils
TBM
6
C (refuel
Visually inspect for loose coils
Stator Winding
Loose coils
TBM
6
C (refuel
Inspect coils for damage
Stator Winding
Damaged coils
TBM
6
C (refuel
Perform capacitance mapping
Stator Winding
Coil stator cooling leakag
OCM FF
6
C (refuel
Inspect visually for water leaks
Stator Winding
Coil stator cooling leakag
TBM
6
C (refuel
Perform stator visual inspectio
Stator Winding
insulation damage
OCM Pre
4
C (refuel
Inspect bearing pits
Grounding Brushes
Inadequate electric conta
OCM Pre
18
M (month
Check brushes for glazing & wi
Grounding Brushes
inadequate electric conta
OCM Pre
18
M (month
Inspect cooler tubes
H2 Coolers
Cooling water leaks
OCM Pre
0
Check cooling water heat rem
H2 Coolers
Inadequate water H2 co
OCM Pre
0
Check (sample) tube deposits
H2 Coolers
inadequate water H2 co
OCM Pre
36
M (month
Check stator cooling water tan
Stator Cooling Water S
Fails to cool stator & rota
0
Record: 1 of 17
ID WorkScope: 786
WS Created: Wed 08/21/2002 15:48
WS Updated: Wed 08/21/2002 15:48
Record: 3 of 11
Workscopes Preview
WS Name/Summary
WS Parameter
UNASSIGNED PM
NORMAL OPERA
OVERHAUL
GENERATOR
MEASURE
VIBRATION
MEASURE
VIBRATION
MEASURE
VIBRATION
REPLACE
FILTER
TREND
PERFORMANCE
OPERATIONS R
INSPECT
BRUSHES
INSPECT
GENERATOR
*Jump to Main Menu Cmd Bttn "Reassign Workscopes"
Add Default WS
Record: 3 of
Client Name Goes Here.
All Rights Reserved. Copyright © (1997-2003)CORE.
Cmp Template Created:
Updated:
Created By: Admin
Updated By: Jim August
Record: 9 of 122
Form View
Start
Microsoft Word - ASM
Exploring C:\RCM\trim
RCMtrim 3.9
NUM
2:28 PM

FIG.17

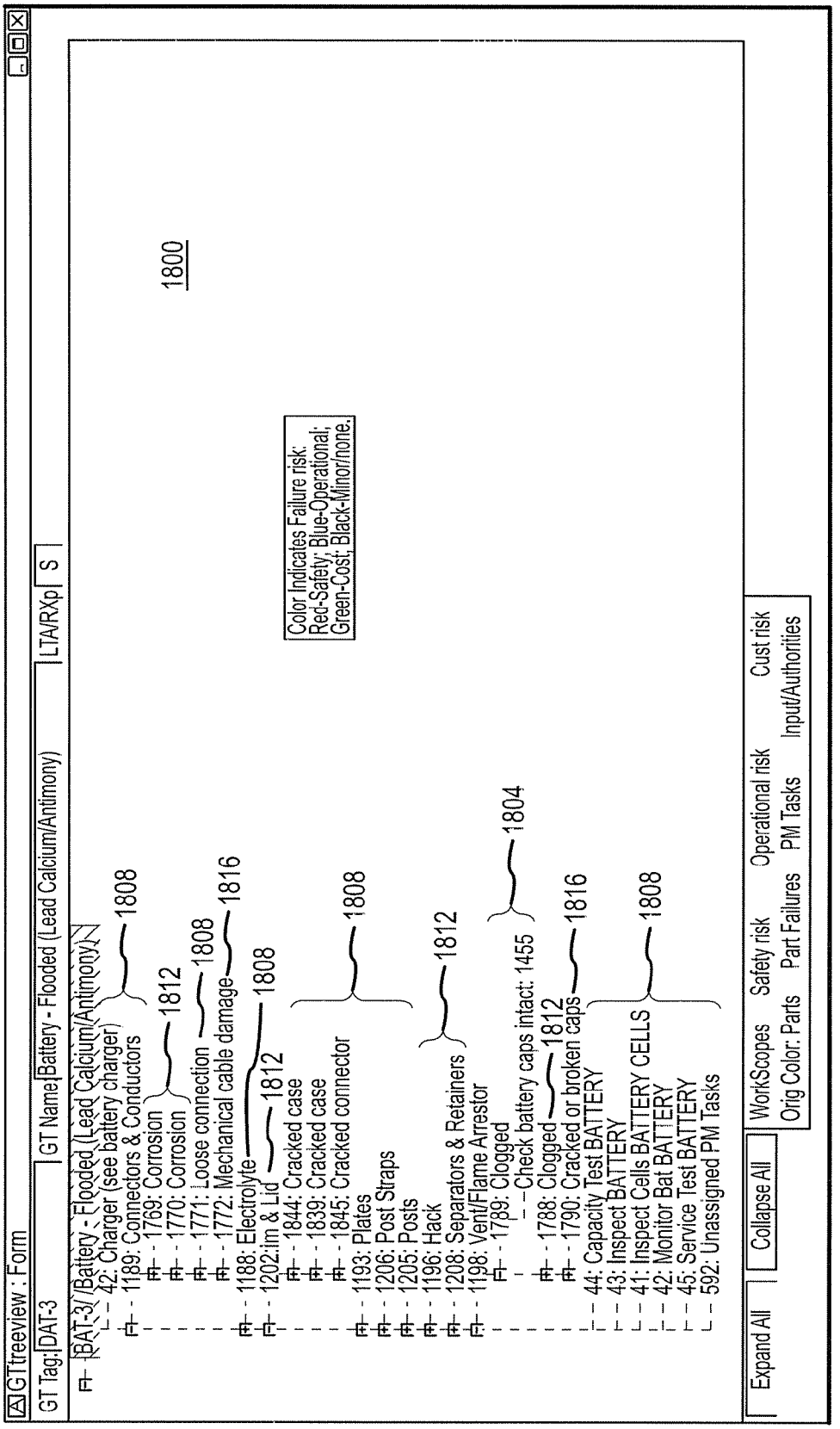
GTtreeview : Form
GT Tag: DAT-3
GT Name: Battery - Flooded (Lead Calcium/Antimony)
LTA/RXp
S
BAT-3 / Battery - Flooded (Lead Calcium/Antimony)
42: Charger (see battery charger)
1189: Connectors & Conductors
1769: Corrosion
1770: Corrosion
1771: Loose connection
1772: Mechanical cable damage
1188: Electrolyte
1202:im & Lid
1844: Cracked case
1839: Cracked case
1845: Cracked connector
1193: Plates
1206: Post Straps
1205: Posts
1196: Hack
1208: Separators & Retainers
1198: Vent/Flame Arrestor
1789: Clogged
Check battery caps intact: 1455
1788: Clogged
1790: Cracked or broken caps
44: Capacity Test BATTERY
43: Inspect BATTERY
41: Inspect Cells BATTERY CELLS
42: Monitor Bat BATTERY
45: Service Test BATTERY
592: Unassigned PM Tasks
1808
1812
1808
1816
1812
1808
1812
1804
1812
1816
1808
1800
Color Indicates Failure risk:
Red-Safety; Blue-Operational;
Green-Cost; Black-Minor/none.
Expand All
Collapse All
WorkScopes
Safety risk
Operational risk
Cust risk
Orig Color: Parts
Part Failures
PM Tasks
Input/Authorities

FIG.18

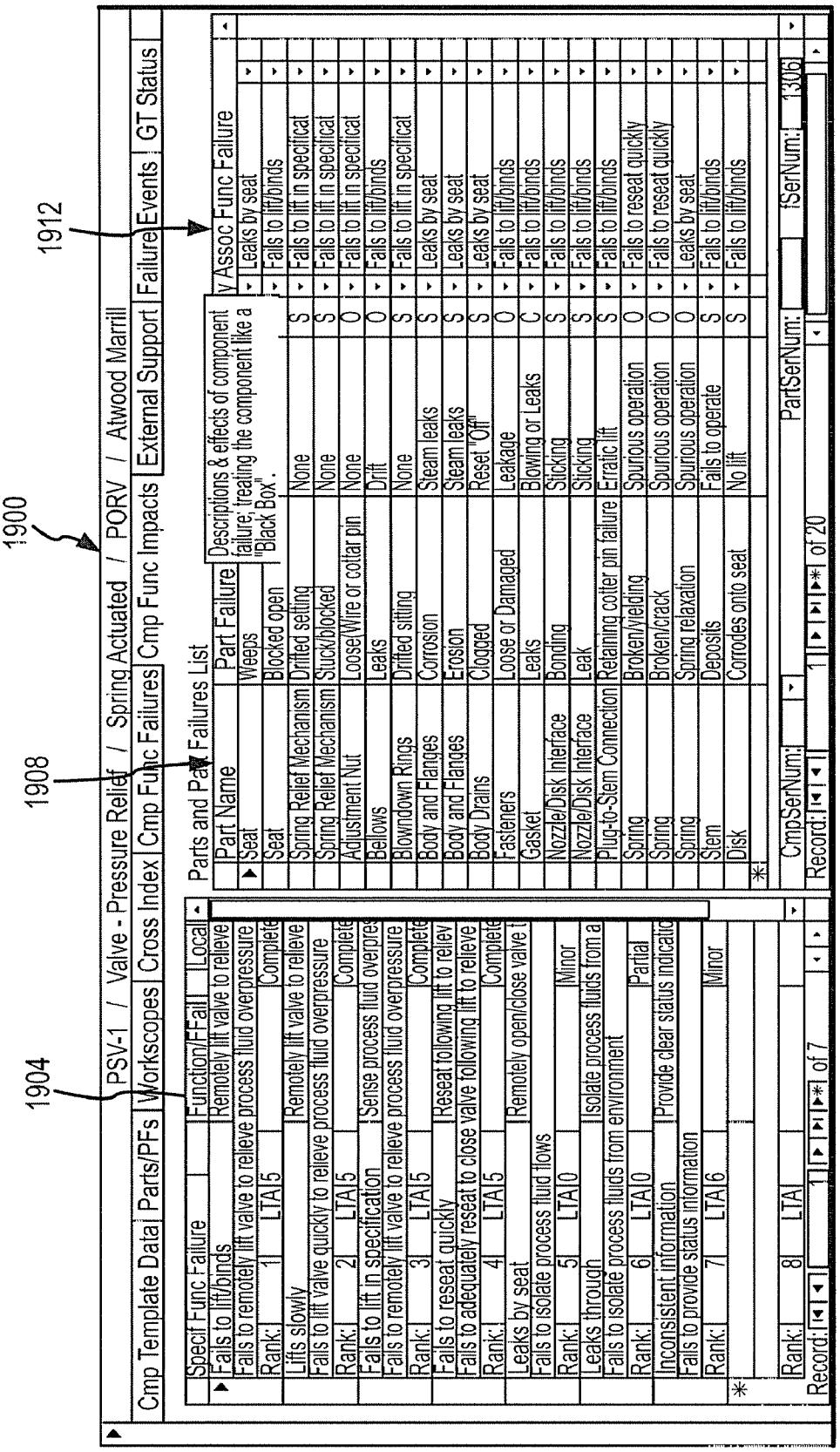
1904
1908
1900
1912
PSV-1 / Valve - Pressure Relief / Spring Actuated / PORV / Atwood Marrill
Cmp Template Data | Parts/PFs | Worksopes | Cross Index | Cmp Func Failures | Cmp Func Impacts | External Support | Failure Events | GT Status
Specif Func Failure
Fails to lift/binds
Fails to remotely lift valve to relieve process fluid overpressure
Rank: 1 LTA 5 Complete
Lifts slowly
Fails to lift valve quickly to relieve process fluid overpressure
Rank: 2 LTA 5 Complete
Fails to lift in specification
Fails to remotely lift valve to relieve process fluid overpressure
Rank: 3 LTA 5 Complete
Fails to reseat quickly
Fails to adequately reseat to close valve following lift to relieve
Rank: 4 LTA 5 Complete
Leaks by seat
Fails to isolate process fluid flows
Rank: 5 LTA 0 Minor
Leaks through
Fails to isolate process fluids from environment
Rank: 6 LTA 0 Partial
Inconsistent information
Fails to provide status information
Rank: 7 LTA 6 Minor
Function/Fail
Remotely lift valve to relieve process fluid overpressure
Remotely lift valve to relieve process fluid overpressure
Sense process fluid overpres
Remotely lift valve to relieve process fluid overpressure
Reseat following lift to reliev
Remotely lift valve to relieve process fluid overpressure
Remotely open/close valve t
Isolate process fluids from environment
Provide clear status indicatio
Local
Parts and Part Failures List
Part Name
Part Failure
Descriptions & effects of component failure; treating the component like a "Black Box".
Assoc Func Failure
Seat
Weeps
Leaks by seat
Seat
Blocked open
Fails to lift/binds
Spring Relief Mechanism
Drifted setting
None
S
Fails to lift in specificat
Spring Relief Mechanism
Stuck/blocked
None
S
Fails to lift in specificat
Adjustment Nut
Loose/Wire or cottar pin
None
O
Fails to lift in specificat
Bellows
Leaks
Drift
O
Fails to lift/binds
Blowndown Rings
Drifted sitting
None
S
Fails to lift in specificat
Body and Flanges
Corrosion
Steam leaks
S
Leaks by seat
Body and Flanges
Erosion
Steam leaks
S
Leaks by seat
Body Drains
Clogged
Reset "Off"
S
Leaks by seat
Fasteners
Loose or Damaged
Leakage
O
Fails to lift/binds
Gasket
Leaks
Blowing or Leaks
C
Fails to lift/binds
Nozzle/Disk Interface
Bonding
Sticking
S
Fails to lift/binds
Nozzle/Disk Interface
Leak
Sticking
S
Fails to lift/binds
Plug-to-Stem Connection
Retaining cotter pin failure
Erratic lift
S
Fails to lift/binds
Spring
Broken/yielding
Spurious operation
O
Fails to reseat quickly
Spring
Broken/crack
Spurious operation
O
Fails to reseat quickly
Spring
Spring relaxation
Spurious operation
O
Leaks by seat
Stem
Deposits
Fails to operate
S
Fails to lift/binds
Disk
Corrodes onto seat
No lift
S
Fails to lift/binds
CmpSerNum:
PartSerNum:
tSerNum: 13066
Record: 1 of 20
Record: 1 of 7

FIG. 19

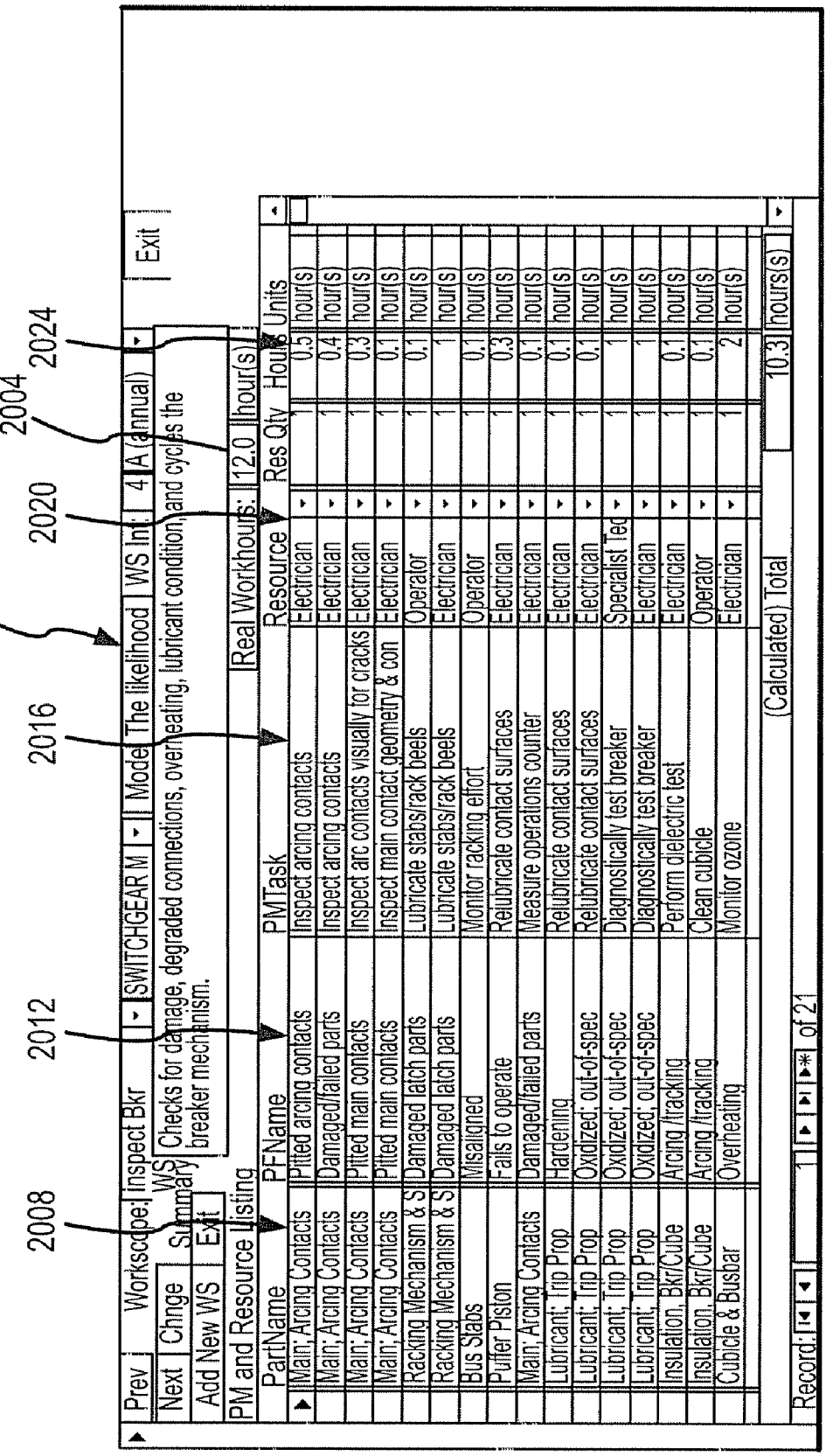
2000
2004
2008
2012
2016
2020
2024
Prev
Worksc
Inspect Bkr
SWITCHGEAR M
Mode
The likelihood
WS In:
4
A (annual)
Exit
Next
Chnge
WS
Checks for damage, degraded connections, overheating, lubricant condition, and cycles the breaker mechanism.
Summary
Add New WS
Exit
PM and Resource Listing
Real Workhours:
12.0
hour(s)
PartName
PFName
PMTask
Resource
Res Qty
Hours
Units
Main; Arcing Contacts
Pitted arcing contacts
Inspect arcing contacts
Electrician
1
0.5
hour(s)
Main; Arcing Contacts
Damaged/failed parts
Inspect arcing contacts
Electrician
1
0.4
hour(s)
Main; Arcing Contacts
Pitted main contacts
Inspect arc contacts visually for cracks
Electrician
1
0.3
hour(s)
Main; Arcing Contacts
Pitted main contacts
Inspect main contact geometry & con
Electrician
1
0.1
hour(s)
Racking Mechanism & S
Damaged latch parts
Lubricate slabs/rack beels
Operator
1
0.1
hour(s)
Racking Mechanism & S
Damaged latch parts
Lubricate slabs/rack beels
Electrician
1
1
hour(s)
Bus Stabs
Misaligned
Monitor racking effort
Operator
1
0.1
hour(s)
Puffer Piston
Fails to operate
Relubricate contact surfaces
Electrician
1
0.3
hour(s)
Main; Arcing Contacts
Damaged/failed parts
Measure operations counter
Electrician
1
0.1
hour(s)
Lubricant; Trip Prop
Hardening
Relubricate contact surfaces
Electrician
1
0.1
hour(s)
Lubricant; Trip Prop
Oxidized; out-of-spec
Relubricate contact surfaces
Electrician
1
0.1
hour(s)
Lubricant; Trip Prop
Oxidized; out-of-spec
Diagnostically test breaker
Specialist Tec
1
1
hour(s)
Lubricant; Trip Prop
Oxidized; out-of-spec
Diagnostically test breaker
Electrician
1
1
hour(s)
Insulation; Bkr/Cube
Arcing /tracking
Perform dielectric test
Electrician
1
0.1
hour(s)
Insulation; Bkr/Cube
Arcing /tracking
Clean cubicle
Operator
1
0.1
hour(s)
Cubicle & Busbar
Overheating
Monitor ozone
Electrician
1
2
hour(s)
(Calculated) Total
10.3
hours(s)
Record:
1
of 21

FIG.20

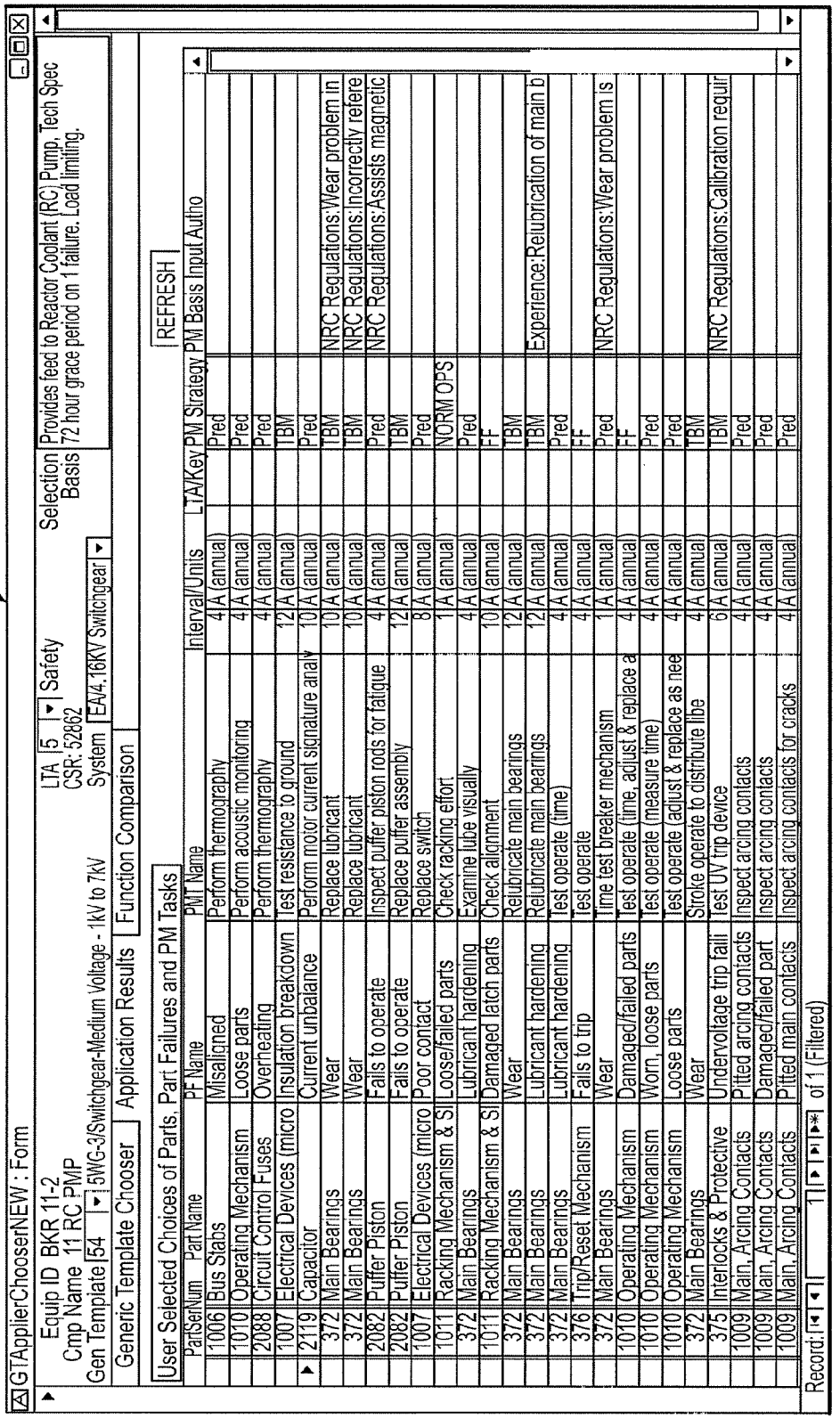
2100
GTApplierChooserNEW : Form
Equip ID BKR 11-2
Cmp Name 11 RC PMP
Gen Template 54 | 5WG-3/Switchgear-Medium Voltage - 1kV to 7kV
LTA 5 | Safety
CSR: 52862
System EA/4.16KV Switchgear
Selection Basis
Provides feed to Reactor Coolant (RC) Pump, Tech Spec 72 hour grace period on 1 failure. Load limiting.
Generic Template Chooser
Application Results
Function Comparison
REFRESH
User Selected Choices of Parts, Part Failures and PM Tasks
PartSeqNum Part Name PF Name PMT Name Interval/Units LTA/Key PM Strategy PM Basis Input Autho
1006 Bus Stabs Misaligned Perform thermography 4 A (annua) Pred
1010 Operating Mechanism Loose parts Perform acoustic monitoring 4 A (annua) Pred
2088 Circuit Control Fuses Overheating Perform thermography 4 A (annua) Pred
1007 Electrical Devices (micro Insulation breakdown Test resistance to ground 12 A (annua) TBM
2119 Capacitor Current unbalance Perform motor current signature analy 10 A (annua) Pred
372 Main Bearings Wear Replace lubricant 10 A (annua) TBM NRC Regulations:Wear problem in
372 Main Bearings Wear Replace lubricant 10 A (annua) TBM NRC Regulations:Incorrectly refere
2082 Puffer Piston Fails to operate Inspect puffer piston rods for fatigue 4 A (annua) Pred NRC Regulations:Assists magnetic
2082 Puffer Piston Fails to operate Replace puffer assembly 12 A (annua) TBM
1007 Electrical Devices (micro Poor contact Replace switch 8 A (annua) Pred
1011 Racking Mechanism & Sl Loose/failed parts Check racking effort 1 A (annua) NORM OPS
372 Main Bearings Lubricant hardening Examine lube visually 4 A (annua) Pred
1011 Racking Mechanism & Sl Damaged latch parts Check alignment 10 A (annua) FF
372 Main Bearings Wear Relubricate main bearings 12 A (annua) TBM
372 Main Bearings Lubricant hardening Relubricate main bearings 12 A (annua) TBM Experience:Relubrication of main b
372 Main Bearings Lubricant hardening Test operate (time) 4 A (annua) Pred
376 Trip/Reset Mechanism Fails to trip Test operate 4 A (annua) FF
372 Main Bearings Wear Time test breaker mechanism 1 A (annua) Pred NRC Regulations:Wear problem is
1010 Operating Mechanism Damaged/failed parts Test operate (time, adjust & replace a 4 A (annua) FF
1010 Operating Mechanism Worn, loose parts Test operate (measure time) 4 A (annua) Pred
1010 Operating Mechanism Loose parts Test operate (adjust & replace as nee 4 A (annua) Pred
372 Main Bearings Wear Stroke operate to distribute lube 4 A (annua) TBM
375 Interlocks & Protective Undervoltage trip faili Test UV trip device 6 A (annua) TBM NRC Regulations:Calibration requir
1009 Main, Arcing Contacts Pitted arcing contacts Inspect arcing contacts 4 A (annua) Pred
1009 Main, Arcing Contacts Damaged/failed part Inspect arcing contacts 4 A (annua) Pred
1009 Main, Arcing Contacts Pitted main contacts Inspect arcing contacts for cracks 4 A (annua) Pred
Record: 1 of 1 (Filtered)

FIG.21

Template	SWG-1	52

Switchgear - Low Voltage

Type	BKR	Manufacturer	Westinghouse
Subtype	LV		

Details

Component Background

Type	Subtype	No.	Name
BKR	LV	SWG-1	Switchgear - Low Voltage
Manuf	Model	Owner	
Westinghouse	52		

Brief

Switchgear - Low Voltage

Complete Description

Low voltage air blast breaker, 13.6 kV and below. Common 4kV application being replaced by vacuum breakers.

Scope

Low Voltage Switchgear include the enclosure, circuit breaker, protective devices, and their accessories:
· Switchgear enclosure including racking mechanism, busbar

Reference/Open Items

1. "Circuit Breaker Maintenance, Volume 1: Low-Voltage Circuit Breakers, Part 1: ABB K Line", EPRI (NMAC) NP-7410s-v1-p1, March 1993.
2. "Circuit Breaker Maintenance, Volume 1: Low-Voltage Circuit Breakers, Part 2: GE AK Models", EPRI (NMAC) NP-7410s-v1-p2, July 1992.
3. "Circuit Breaker Maintenance, Volume 1: Low-Voltage Circuit Breakers, Part 3: Westinghouse DB Models", EPRI (NMAC) NP-7410s-v1-p3, December 1992.
4. "Circuit Breaker Maintenance, Volume 1: Low-Voltage Circuit Breakers, Part 4: Westinghouse DS Models", EPRI (NMAC) NP-7410s-v1-p4, December 1992.
5. "Comprehensive Low-Cost Reliability Centered Maintenance", EPRI TR-105365, June 1995.
6. "EPRI Reliability Centered Maintenance Technical Handbook", EPRI TR-100320, January 1992.
7. "Guide for Determining Preventive Maintenance Task Intervals", EPRI TR-103147, December 1993.
8. NRC Information Notice 96-46, "Zinc Plating of Hardened Metal Parts and Removal of Protective Coatings in Refurbished Circuit Breakers". (Addresses the concern that NLI/NSS may have not identified all of the zinc-plated parts in low and medium voltage circuit breakers manufactured by General Electric and Westinghouse.)

ANSI C37.50-1989, Low-Voltage AC Power Circuit Breakers Used in Enclosures-Test Procedures, arranged as follows: Section 1-General; Section 2-General Test Conditions and Requirements; Section 3-Design Test Requirements; Section 4-Accessory Devices; Section 5-Treatment of Failures within Test Sequences; Section 6-Production Tests; and Section 7-Production Monitoring and Product Test Requirements.

This ANSI standard relates only to manufacturing of the PCB. Each manufacturer supplies instructions for performing its recommended tests. These tests may differ from one manufacturer to another, making it difficult to standardize on any testing procedure. You can use the NETA standards to help develop a standardized testing routine for PCBs. The ANSI standard does give good detail on the following tests:

Trip-device calibration,
AC dielectric withstand-voltage,
Continuous current,
Overload switching,
Endurance,
Short-circuit current, and

FIG.22A

Short-time current.

NETA recommends using its standards with any applicable manufacturer standard. Of course, you still should use qualified personnel who are trained and certified in the equipment and test methodology. PCB test equipment is much the same type as MCCB test equipment.

Additional Basis Information

Expert-identified common dominant failure location/mechanisms:
· Circuit breaker operating mechanism
· Circuit breaker & cubicle racking mechanism
· Circuit breaker main current, arc quenching, insul components
· Electrical devices and wiring

Equipment Name

the switchgear enclosure, circuit breaker, protective devices, and their accessories, as follows:

· Switchgear enclosure including racking mechanism, busbar and insulation, cabinets, interlocks and switches, lightning arrestors, bus PTs (potential tran

Functions/Failures

Rank	Component Function(s)/Failures	Consequences	Degree
1	Contain & suppress arc flash Fails to contain arc flash	Flashover	Complete
2	Trip on fault Fails to trip on fault	Fails to trip on fault	Complete
3	Allow normal load disconnect Fails to allow normal disconnect routing ON DEMAND	Fails to disconnect loads	Complete
4	Power loads from high voltage bus Fails to power loads from high voltage bus	Fails to close in on load	Complete
5		Spurious trips	Partial
6	Facilitate maintenance Fails to facilitate maintenance	Can't clear equipment for maintain	Partial
7	Control maintenance cost Fails to control maintenance cost	Unnecessary maintenance cost	Complete
8	Provide satus Fails to provide system status	Fails to provide status	Minor

Parts

No.	Part/*Alternate Name*	Functions	Notes
4b	Arc Chutes *Arc Chutes Quench*	Cool, control and suppress eclecti	Verify adjustments · Inspect puffer and verify operation · Perform ductor test · Perform insulation resistance tests · Calibrate protective devices as required · Perform overcurrent trip test · Perform as-left electrical open/close and timing test

FIG.22B

8c	Aux Switches/Contacts	Provide auxiliary control functions	
7b	Bus CT/PTs *Current Transformer*	Power control circuits and relays i	
1c	Bus Stabs	Connect breaker to bus and load	The normal heating effect of the main current may be allowed for by comparing the breaker or cubicle temperature with that of neighboring breakers carrying similar loads or by trending the temperature readings of a particular unit over time. The recommended period for thermographic inspection is 1 year because of the quick, non-intrusive nature of the task and the ease with which many adjacent cubicles can be surveyed at one time and location. This task interval is significantly shorter than the times to first failure anticipated from the above failure causes, and results in thermography being an effective condition monitoring task for those failure causes. Consideration should be given to extending thermographic scan intervals taking into account breaker loading conditions and previous thermographic histories.This task detects temperature increases, associated with main current carrying components, caused by degraded or loose connections, or contacts. The interval is not supported by the failure mode data so that some interval extension could be possible, eve
1a	Cabinet	Protect breaker and cube controls;	
8b	Controls Cubicle *Programmable Logic Controller (PLC).*	House and protect controls	
1b	Cubicle	Provide controlled environment	Cubicle Detailed Inspection may not be carried out at the same time as the Breaker Detailed Inspection, although it may be convenient to synchronize the inspections and overhauls. Inspection of buswork will be visual and by thermography as described in the thermography task for breaker and cubicle. Line and load side insulation should be visually inspected and have its insulation resistance tested.
3c	Electrical Devices (micro switch *Electrical Devices (micro switches, aux.*	Sense position for interlocks, coin	Electrical Devices (micro switches, aux. switches, secondary disconnects, fuse blocks, aux. relays, charging motor, heaters)
9b	Indications	Provide status	
3	Insulation, Phase/Main *Electric Insulation*	Insulate voltage from ground; cont	
8a	Interlocks & Protective Devices	Prevent closed breaker racking on	Prevent operations that are inherently dagerous or consume breaker life.
7a	Lightning/Surge Arrestors	Ground high voltage spikes	Usually not applied below 4kV level SWGR

FIG.22C

5a	Lubricant	Lubricate operating mechanism be	All of the failure mechanisms discussed above progress continuously for a period of years before the failure point is reached. The minimum duration of this wearout characteristic is usually controlled by the service conditions that affect lubrication failure. Preventive maintenance (PM) within this period can identify and intercept all the failure mechanisms excepting those due to design, manufacturing, and installation defects, and maintenance error. These are excluded from consideration here because their random nature does not lend itself to being addressed by regularly scheduled PM tasks, other than failure finding such as the operability test, trip tests, or calibration. An overhaul is necessary to completely clean out old lubricant and to renew lubricant at every point in the breaker within about 10 years for low duty cycle and mild service conditions. The detailed inspection should be performed in order to replace as much of the lubricant as possible at a shorter interval, about half the overhaul interval. In a Detailed Inspection, accessible pivot points and bearings can be lubricated, although they probably still can not be properly cleaned. Manual and electrical operation can help to distribute lubricant in all areas and mix it to prevent separation of its constituents. The "feel" of the operating mechanism during manual operation can indicate to an experienced person the general condition of the lubricant. Additionally, the time taken for the breaker to close is a direct indication of a sluggish mechanism. As-found and as-left electrical close-timing tests may be supplemented by a trip load test or by a minimum control voltage test to detect a sluggish mechanism. If the breaker does not pass these tests a detailed inspection or overhaul will be necessary. A Detailed Inspection will typically be performed to ensure that critical breakers in severe service conditions (e.g. high temperatures, high humidity, and salt laden air) can reach the scheduled overhaul at 8 years. In more normal conditions for critical breakers, detailed inspection can be combined in rotation with visual inspection and overhaul to provide flexibility on when the overhaul is performed (i.e. not strictly at 10 years). Calibration tasks for the protective devices, instantaneous overcurrent, time-current excess, overvoltage and undervoltage, as appropriate, should follow the requirements of technical specifications. These tasks help to ensure that the protective relays are not already out-of-specification (failed) when needed. Where there are no technical specification requirements the

FIG.22D

			recommended period for calibration can be paired with that of the breaker detailed inspection. At this interval, experience shows that the relays are not usually sufficiently out-of-calibration to be in a failed state.This task is a more detailed check for damage, degraded connections, and signs of overheating, checks the condition of the lubricant, and cycles the breaker mechanism. The interval is strongly determined by a large number of common wearout failure mechan
	Mechanism lubricant		
3a	Main & Arcing Contacts	Carry current load closed; back up	
5	Operating Mechanism	Open on fault; close on load dema	Although the functional test is not recommended as a scheduled task, it is nevertheless recommended that the breaker be operated at least once per operating cycle for all critical and non-critical but important breakers. Any breaker, regardless of its functional importance, which remains in a static position for long periods of time, e.g. longer than 2 refueling cycles, should be functionally tested for the above reasons. Otherwise, the functional test should be performed when: · Returning powered equipment to service · As per technical specifications . As a post maintenance test The functional test is an electrical open and close test which mixes the lubricant and ascertains that the breaker operating mechanism is functional. The interval is not strongly constrained by the failure mode data, but not much latitude exists for inte
	Charging Mechanism		
3b	Puffer Piston	Extinguishes arc blowing it into the	
1b1	Racking Mechanism / Shutter A	Allow maintenance and replaceme	
9a	Sensors	Sense contactor breaker positions	Trip latch Charging spring Open/closed position Racking

FIG.22E

5b	Trip Mechanism	Trip operating mechanism	Failure mechanisms discussed above progress continuously for a period of years before the failure point is reached. The minimum duration of this wearout characteristic is usually controlled by the service conditions that affect lubrication failure. An overhaul is necessary to completely clean out old lubricant and to renew lubricant at every point in the breaker within about 12 years for low duty cycle and mild service conditions. The detailed inspection should be performed in order to replace as much of the lubricant as possible at a shorter interval, about half the overhaul interval. The breaker overhaul is a complete disassembly to give access to all parts for cleaning, inspection for damage and wear, and complete replacement of lubricant. The interval is strongly determined by a large number of common wearout failure mechanisms aff

Work Orders

	Workscope	Summary
1	Inspect Swgr Cube SWITCHGEAR C	4 A (annual)
	Check racking mechanism lubrication, damaged /failed parts, and loose or missing fasteners.	The racking mechanism is subject to lubrication failure, damaged and failed parts, and loose or missing fasteners. Inadequate lubrication is an important cause of failures in the cubicle as it was in the breaker, although the consequences are more likely to be extended maintenance time rather than a critical event such as breaker failure to close or to trip. Assessment of the condition of the lubricating grease should be the prime objective of a cubicle inspection. A visual check of the lubricant at accessible, and hence more frequently lubricated points, should be done but will not provide a reliable assessment of its condition at other points, such as bushings and bearings, which can only be lubricated at overhaul. Hard lubricant in thin films may not be visible at all, or may appear as a varnish-like layer. Parts that are loose, damaged, or missing may be seen directly, often where they should not be, even by relatively inexperienced personnel. However, signs of material fatigue, abnormal wear, or material property changes can best be noted and assessed by having experienced people perform the inspection. Relatively common problem areas are the alignment of the breaker interface with the cubicle, and alignment problems causing damage to contacts, and to primary and secondary disconnects and switches.

FIG.22F

2	Inspect Test Bkr SWITCHGEAR Check for damage, degraded connections, and signs of overheating, lubricant condition and cycles breaker mechanism.	4 A (annual) The Detailed Inspection includes a comprehensive set of tasks designed to be an effective way to thoroughly check the operating mechanism, main current components, and the racking mechanism for mechanically worn, failed or damaged parts, loose connections and fasteners, too check the condition of the lubricant (and to cycle the operating mechanism so as to mix and distribute the lubricant), to provide an opportunity to add and refresh lubricant, and to check for burn marks or discoloration that might indicate overheating of electrical components such as relays, coils and switches. Parts that are loose, damaged, or missing may be seen directly, often where they should not be (e.g. on the cubicle floor), even by relatively inexperienced personnel. However, signs of material fatigue, abnormal wear (e.g. worn bushings), or material property changes can best be noted and assessed by having experienced people perform the detailed inspection. A relatively common problem area is the alignment of the prop mechanism, its centering and tightness. The condition of the lubricant is essential to proper operation. Inadequate lubrication is by far the dominant cause of breaker failures. Assessment of the condition of the lubricating grease should therefore be the prime objective of any inspection. Removal of arc chutes, phase barriers, inspection covers and relay/switch covers will facilitate a fairly thorough check of lubricant condition. However, the detailed inspection does not include extensive disassembly of the breaker; consequently, lubricant internal to bearings and bushings will not, in general, be accessible at the detailed inspection. Hard lubricant in thin films may not be visible at all, or may appear as a varnish-like layer. Contaminated switches and relay contacts make up a very large proportion of the failure causes and overhaul deficiencies noted in NPRDS failure events and NMAC data analysis. These contacts should be accessible at a detailed inspection when switch covers are removed. Electrical insulation and wiring is a much smaller contributor to breaker failure. In addition to visible damage to primary contacts, and deposits and tracking on arc quenching components, the arc contact tips may be damaged or broken off, and the puffer or the blowout coil may have failed. MCCB standards. NEMA publishes Standards Publication AB 4-1996, Guidelines for Inspection and Preventive Maintenance of Molded Case Circuit Breakers Used in Commercial and Industrial Applications. It's arranged as follows: Section 1-General; Section 2-Guidelines; Section 3-Inspection Procedures; Section 4-Preventive Maintenance; Section 5-Test Procedures; and Section 6-Accessory Device Test Procedures. AB 4-1996 mentions these tests: Mechanical operation tests, Insulation resistance test, Individual pole resistance test (millivolt drop), Inverse-time overcurrent trip test, Rated hold-in test, and Instantaneous overcurrent trip test. The NETA specification includes these tests except the rated hold-in test. It also lists two additional tests: short-time pickup and delay test and ground-fault pickup and time delay test. Performing the NETA or NEMA tests, you must use, at minimum, a megohmmeter, current injection test set, digital multimeter, and a variable voltage supply.

FIG.22G

		NEMA AB-4 gives detailed and systematic instructions for doing each test. The NETA specifications include a list of the tests, assuming a qualified and certified person performs the tests. They do not include methodology or "how-to" information. NEMA AB-4 mentions certain sections set guidelines for inspection, preventive maintenance, and testing. But, it lets you decide what sections to use for a good program. The NETA specifications list a multitude of tests for maintenance or acceptance testing. As with NEMA AB-4, you can decide whether to perform certain tests.	
3	Operations Rounds Detects sensing line air leaks, performs routine trouble checks, monitors the equipment environment, detects unusual noises, fluid leaks, and monitors operational parameters like DT & DP.		1 W (week)
4	Overhaul Bkr SWITCHGEAR Complete disassembly for cleaning, inspection, and lubricant replacement.	The failure locations and failure causes addressed by the Overhaul are the same as those addressed by the Detailed Inspection. However, in an overhaul the breaker is completely disassembled to give access to all parts for cleaning, inspection for damage and wear, and complete replacement of lubricant. Failure to do this results in wearout of the lubricant in parts inaccessible to the detailed inspection. In addition, an overhaul parts replacement kit should be used for small mechanical items like retainers, washers, nuts and bolts, bushings, gaskets and springs. Individual subcomponent replacement depending on make and model may also be necessary. The NMAC maintenance guides for low voltage circuit breakers and the appropriate vendor manuals should be consulted for parts to replace at the overhaul. Calibration tasks for the protective devices, instantaneous overcurrent, time-current excess, overvoltage and under voltage, as appropriate, should follow the requirements of technical specifications. These tasks help to ensure that the protective relays are not already out-of-specification (failed) when needed. Where there are no technical specification requirements the recommended period for calibration can be paired with that of the breaker overhaul. At this interval, experience shows that the relays are not usually sufficiently out-of-calibration to be in a failed state.	8 A (annual)

FIG.22H

5	Test Swgr SWITCHGEAR Electrical open & close test exercising breaker operating mechanism, which redistributes the lubricant.		4 A (annual) The functional test is not recommended as a scheduled task, but it is nevertheless recommended that the breaker be operated at least once per operating cycle for all critical and non-critical but important breakers. Any breaker, regardless of its functional importance, which remains in a static position for long periods of time, e.g. longer than 2 refueling cycles, should be functionally tested for the above reasons. This does not test protective trip mechanisms but it ascertains that the breaker operating mechanism is functional and it mixes the lubricant to help prevent seizing of the mechanical parts. The functional test is an electrical open and close test normally conducted as a post maintenance test on the breaker and also frequently as a post maintenance test on the load. MCCB standards. NEMA publishes Standards Publication AB 4-1996, Guidelines for Inspection and Preventive Maintenance of Molded Case Circuit Breakers Used in Commercial and Industrial Applications. It's arranged as follows: Section 1-General; Section 2-Guidelines; Section 3-Inspection Procedures; Section 4-Preventive Maintenance; Section 5-Test Procedures; and Section 6-Accessory Device Test Procedures. AB 4-1996 mentions these tests: Mechanical operation tests, Insulation resistance test, Individual pole resistance test (millivolt drop), Inverse-time overcurrent trip test, Rated hold-in test, and Instantaneous overcurrent trip test. The NETA specification includes these tests except the rated hold-in test. It also lists two additional tests: short-time pickup and delay test and ground-fault pickup and time delay test. Performing the NETA or NEMA tests, you must use, at minimum, a megohmmeter, current injection test set, digital multimeter, and a variable voltage supply. NEMA AB-4 gives detailed and systematic instructions for doing each test. The NETA specifications include a list of the tests, assuming a qualified and certified person performs the tests. They do not include methodology or "how-to" information. NEMA AB-4 mentions certain sections set guidelines for inspection, preventive maintenance, and testing. But, it lets you decide what sections to use for a good program. The NETA specifications list a multitude of tests for maintenance or acceptance testing. As with NEMA AB-4, you can decide whether to perform certain tests.

FIG.22I

6	Thermography SWITCHGEAR	1 A (annual)
	Detects current-carrying component hot spots caused by loose connections or bus stabs. Without special switchgear windows, not safe to perform on energized equipment. Normally shot from the back of the bus works, but possible in front for controls.	Thermography will detect increases in temperature that affect the whole cubicle, as well as accessible areas of the buswork. Typically such temperature increases will be associated with main current carrying components and will be caused by loose or contaminated connections, or bus stabs that are misaligned, damaged, or contaminated. ANSI C37.50-1989, Low-Voltage AC Power Circuit Breakers Used in Enclosures-Test Procedures, arranged as follows: Section 1-General; Section 2-General Test Conditions and Requirements; Section 3-Design Test Requirements; Section 4-Accessory Devices; Section 5-Treatment of Failures within Test Sequences; Section 6-Production Tests; and Section 7-Production Monitoring and Product Test Requirements. This ANSI standard relates only to manufacturing of the PCB. Each manufacturer supplies instructions for performing its recommended tests. These tests may differ from one manufacturer to another, making it difficult to standardize on any testing procedure. You can use the NETA standards to help develop a standardized testing routine for PCBs. The ANSI standard does give good detail on the following tests: Trip-device calibration, AC dielectric withstand-voltage, Continuous current, Overload switching, Endurance, Short-circuit current, and Short-time current. NETA recommends using its standards with any applicable manufacturer standard. Of course, you still should use qualified personnel who are trained and certified in the equipment and test methodology. PCB test equipment is much the same type as MCCB test equipment.
7	Unassigned PM Tasks	0
	Do not delete this placeholder record.	

Work Orders (workscope)

	Task	Part	Failure
1	Thermography SWITCHGEAR		1 A (annual)
	1 Perform thermographic survey	Bus Stabs	Overheating
	2	Main & Arcing Contacts	Corroded contacts
	3	Main & Arcing Contacts	Pitted contacts
2	Inspect Test Bkr SWITCHGEAR		4 A (annual)
	1 Inspect chutes	Arc Chutes	Flashover (fail to quench)
	2 Measure dielectric resistance	Arc Chutes	Flashover (fail to quench)
	3	Arc Chutes	Flashover (fail to quench)
	4 Measure dieletric ground strength	Arc Chutes	Ground
	5 Inspect arc chutes visually for cracks	Arc Chutes	Ground
	6 Clean arc chutes	Arc Chutes	Flashover (fail to quench)
	7 Check seal gasket visually	Cabinet	Gasket won't seal

FIG.22J

	8	Vacuum dust	Cabinet	Dust
	9	Chek grounds	Electrical Devices (micr	Insulation breakdown
	10	Check contact resistance	Electrical Devices (micr	Contact resistance
	11	Test ground insulation resistance	Insulation, Phase/Main	Insulation thermal breakdo
	12	Test insulation resistance	Insulation, Phase/Main	Contamination insulation
	13	Test operate	Lubricant	Trip latch oxidation product
	14	Relubricate contact surfaces	Main & Arcing Contacts	Pitted/corroded contacts/da
	15	Inspect contacts	Main & Arcing Contacts	Corroded contacts
	16	Inspect lever mechanism welds for cracks	Operating Mechanism	Cracked welds
	17	Time test operate	Operating Mechanism	Loose parts
	18	Check area vibration loads	Operating Mechanism	Worn parts
	19	Monitor normal racking interlocks	Racking Mechanism / S	Erroneous interlock operati
	20	Relubricate slide contact surfaces	Racking Mechanism / S	Worn, loose or failed parts
	21	Verify normal indications	Racking Mechanism / S	Worn, loose or failed parts
	22	Visually inspect switch hardware	Sensors	Failed input limit switch se
	23	Relubricate trip collapsing prop	Trip Mechanism	Slow
3	Overhaul Bkr SWITCHGEAR			8 A (annual)
	1	Replace chutes	Arc Chutes	Flashover (fail to quench)
	2	Replace arc chutes	Arc Chutes	Flashover (fail to quench)
	3		Arc Chutes	Ground
	4	Relubricate latch contact surfaces	Lubricant	Trip latch oxidation product
	5	Relubricate main bearing	Lubricant	Hardened main bearing lube
	6	Replace contacts	Main & Arcing Contacts	Pitted contacts
	7		Main & Arcing Contacts	Pitted/corroded contacts/da
	8	Test puffer blowout	Puffer Piston	Weak puff
	9	Relubricate collapsing mechanism/test trip	Trip Mechanism	Fails to trip
4	Inspect Swgr Cube SWITCHGEAR CUBE			4 A (annual)
	1	Check area conditions	Bus Stabs	Overheating
	2	Test operate under surveillance	Electrical Devices (micr	Fail to sense position
	3	Stroke operate	Lubricant	Hardened main bearing lube
	4	Monitor racking effort required	Racking Mechanism / S	Worn, loose or failed parts
	5	Test time operation	Trip Mechanism	Slow
5	Test Swgr SWITCHGEAR			4 A (annual)
	1	Check cube conditions	Cubicle	Moisture contamination
	2	Test operate	Electrical Devices (micr	Contact resistance
	3		Electrical Devices (micr	Misaligned/loose
	4	Test surge protection	Lightning/Surge Arresto	Fails to ground
	5	Time test operate	Lubricant	Hardened main bearing lube
	6	Test operate	Operating Mechanism	Worn parts
	7	Test accoustically	Operating Mechanism	Worn parts

FIG.22K

6 Operations Rounds			1 W (week)
1 Monitor instruments		Bus CT/PTs	Open
2 Check operations status indications		Indications	Erroneous status

Authorties

Application Tag(s)	Component Name		SYSTEM	
BKR SWG-1	Switchgear - Low Voltage		52	55318 ☑
Applications/Users				
03683N-012	480V BREAKER	Westinghouse	EB	480V Switchgea
1-52/RTB	U1 RX TRIP BKR	S		
1-52/RTA	U1 RX TRIP BKR	S		
1-52/BYB	U1 RX TRIP B-P BKR			
1-52/BYA	U1 RX TRIP B-P BKR			
1-24Y7274B	BREAKER	S		
1-24Y7273B	BREAKER	S		
03683P-01259	480V BREAKER	S		
03683O-01259	480V BREAKER	S		
03683N-01259	480V BREAKER	S		

BKR SWG-1	Switchgear - Low Voltage		52	47564 ☑
Applications/Users				
7004301	122A SYS 1 SEPTIC TN	Westinghouse	DE	Water Tr
7004402	NEW ADMIN BLDG SEPTIC PM	C		
7004401	NEW ADMIN BLDG SEPTIC PM	C		
7004302	122B SYS 1 SEPTIC TNK SUB	C		
7004301	122A SYS 1 SEPTIC TNK SUB	C		

FIG.22L

Template	MOT-1	39

Moto - Direct Current

Type	MOT	Manufacturer	US Motors
Subtype	DC		
Details			
Component Background			

Type	Subtype	No.	Name
MOT	DC	MOT-1	Motor - Direct Current
Manuf	Model	Owner	
US Motors	39		

Brief

Motor - Direct Current

Complete Description

Small motor for emergency power in loss of AC power event

Scope

DC electric motor includes:
· Electric motor and motor shaft excluding the coupling
· All power, sensing, and control cables up to but not including the DC breaker
· Motor mo

Reference/Open Items

1. "Electric Motor Predictive and Preventive Maintenance Guide", EPRI (NMAC) NP-7502, July 1992.
2. "Manual of Bearing Failures and Repair in Power Plant Rotating Equipment", EPRI GS-7352, July 1991.
3. "Electrical References Series: Vol. 6 - Motors", EPRI EL-5036-V-6.
4. "Guidelines for the Selection, Procurement, and Acceptance of Nuclear Safety Related Mild Environment Motor Insulation for Rewinds", EPRI TR-103585.
5. "Guidelines for the Selection, Procurement, and Acceptance of Nuclear Safety Related Harsh Environment Motor Insulation for Rewinds", EPRI TR-104872.
6. "Guidelines for the Repair of Nuclear Power Plant Safety-Related Motors (NCIG-12), EPRI NP-6407, March 1990.
7. NRC Information Notice 94-51, "Inappropriate Greasing of Double Shielded Motor Bearings"
8. ASME Guide OM-S/G-1994 Part 14, "Vibration Monitoring of Rotating Equipment in Nuclear Power Plant"

Electrical Signature Analysis (ESA) uses the electric motor as a transducer to detect electrical and mechanical faults through a significant portion of the motor system. Usually used as a go/no go test, ESA does have some trending capabilities, but will normally only detect winding faults and mechanical problems in their late stages. Some manufacturers are sensitive to load variations and readings will vary based upon the load. Requires nameplate information and many systems require the number of rotor bars, stator slots and manual input of operating speed.

Motor Circuit Analysis (MCA) testing: Instruments using combinations of values for resistance, impedance, inductance, phase angle, current: frequency response, capacitance and insulation testing can be used to troubleshoot, commission and evaluate control, connection, cable, stator, rotor, air gap and insulation to ground health. Using a low voltage output, readings are read through a series of bridges and evaluated. Non-destructive and trendable readings often months in advance of electrical failure. Note: Different manufacturers of this technology use different combinations of test values.

Several common approaches within industry as well as several new ones use a combination of energized and de-energized testing. Energized testing is best under constant load conditions and trended in the same operating conditions each time.

One common approach has been the use of insulation resistance and/or polarization index. These only identify insulation to ground faults in both the motor and cable, which represents under 1% of the overall motor system faults (~5% of motor faults).

Infrared and vibration are normally used in conjunction with each other with success. However, they miss a few common problems or only detect them in the late stages of failure.

FIG.23A

Surge testing and high potential testing will only detect some winding faults and insulation to ground faults, with the potential to take the motor out of action should any insulation contamination or weakness exist.

MCA and ESA support each other and detect virtually all of the problems in the motor system. This accuracy requires MCA systems that use resistance, impedance, phase angle, I/F and insulation to ground and ESA systems that include voltage and current demodulation.

The newest, and most effective approach has been vibration, infrared and MCA and/or ESA. This approach combines electrical and mechanical evaluation and troubleshooting. As found in the Motor Diagnostic and Motor Health Study,[3] 38% of motor system testing involving only vibration and/or infrared see a significant return on investment. This number jumped to 100% in systems that used a combination of MCA/ESA along with vibration and/or infrared.

Additional Basis Information

Expert-identified dominant failure locations:
- Brush wear; holder spring tension/connections, & commutator
- Bearings (continuous)
- Stator winding (starts, hi temps, insulation)
- Mechanical electrical connections & terminations (windings/leads)

Equipment Name

- Electric motor and motor shaft excluding the coupling
- All power, sensing, and control cables up to but not including the DC breaker
- Motor mounting and base
- Internal motor heaters

Functions/Failures

Rank	Component Function(s)/Failures	Consequences	Degree
1	Provide trip coordination with other functions Fails to provide coordinate trips	Fails interface coordination	Partial
2	Provide heat removal safety Fails to provide heat safe removal	Overheats	Complete
3	Provide load Fails to power, start and run load	Can't maintain load	Partial
4	Trip on overload Fails to trip on overload	Fails to trip on overload	Complete
5	Trip load on shutdown Fails to trip on load on shutdown	Won't trip normally	Complete
6	Start and run load on demand Fails to start and run load	Won't start	Complete
7	Run load meeting load requirement	Won't run load	Complete
8	Provide load status	Fails to provide status	Minor

Parts

No.	Part/*Alternate Name*	Functions	Notes
1b	Air Inlet Openings	Allows air entrance for cooling, ve	

FIG.23B

5a	Bearing Lubrication Oil (LO)	Provide sliding lubricant preventin	The observation of clogged air inlets, loose or damaged conduits or seal flex, and the detection of audible noise, are simple tasks that can be covered by operator rounds, rather than by a scheduled PM task. Although it may be convenient to address the visual inspection items in operator rounds for critical motors, there does not appear to be a need to make these observations as often as every shift. For particularly large and critical DC motors it will be worth including activities analogous to the on-line mechanical tests for medium voltage motors. These would consist of using plant instrumentation to trend motor current and bearing temperatures at intervals of 6 months for high cycle motors, and 12 months for standby motors. For these motors an internal visual inspection similar to the off-line task for medium voltage motors might also be appropriate.
	Lube Oil		
5c	Bearing Seals	Separate bearing lube oil/grease fr	
5b2	Bearings: Antifriction	Align rotor allowing rapid dynamic	Suggested interval of 3 months is a conservative starting point with this new technology to make acoustic monitoring an effective detection method for a range of grease-related failure causes. However, there may be dangers in applying the technology, e.g. if it promotes the addition of grease to bearings which are double shielded, or if it promotes overgreasing. Consideration should be given to installing new grease fittings which prevent the addition of grease when the grease pressure in the bearing reaches 20 psi, and/or fittings which relieve internal grease pressure when it rises to a preset threshold.Acoustic monitoring is focused on addressing grease-related causes of wear in bearings and other rotating components. There is little latitude for interval extension for critical motors because of the significant number of random failure mechanisms invol
	Bearings & Shaft		

FIG.23C

5b1	Bearings: Journal	Align bearings for standard, warm	Vibration monitoring addresses a wide range of degradations in DC motors, only about a third of which are also covered by another task. This makes vibration monitoring a very important part of the PM program. Most of the degradations addressed by vibration monitoring lead to a fairly random occurrence of failures. However, continuously running motors are subject to much more rapid wear on the brushes, bearings, armature, commutator, and shaft than is the case for standby motors. Consequently, the suggested interval of 6 months for continuously running critical motors should be sufficiently frequent to permit vibration monitoring to detect almost all failures from the above degradation modes before they occur. Standby motors will generally have a much lower wear rate, although no wearout pattern is observable.
	No slingers with grease lubed bearings		
2b	Electrical Connections	Connect major electrical conducto	On suggestions from the Large Electric Motors Users Group, LEMUG, the Bridge Test should be performed every second outage, say at 3 to 4 years, but only for critical motors with power above 20 HP. If the Bridge Test is performed at all for critical motors below 20HP, the interval should be longer, for example, at 4.5 or 6 years.
	Connections		
1b	Fan & Cooling Air Filters	Provide clean chilled cooling air to	The observation of clogged air inlets, loose or damaged conduits or seal flex, and the detection of audible noise, are simple tasks that can be covered by operator rounds, rather than by a scheduled PM task. Although it may be convenient to address the visual inspection items in operator rounds for critical motors, there does not appear to be a need to make these observations as often as every shift. For particularly large and critical DC motors it will be worth including activities analogous to the on-line mechanical tests for medium voltage motors. These would consist of using plant instrumentation to trend motor current and bearing temperatures at intervals of 6 months for high cycle motors, and 12 months for standby motors. For these motors an internal visual inspection similar to the off-line task for medium voltage motors might also be appropriate.

FIG.23D

2c	Feeder Cables and Motor Lead	Provide power feed to motor from	Cables – Before and After the Controls Common cable problems: · Thermal breakdown due to overloads or age · Contamination in cables that pass underground through conduit · Phase shorts as well as grounds caused by 'treeing' or physical damage. · Opens due to physical damage. · Physical damage occurs combined with other cable problems.
1a	Frame, Enclosure, & Mounting	Support and enclose rotor providin	
9	Instrumentation	Provide status	NA reference only
5a1	Lubrication Supply *LO Supply; LO Feed; LO Bearing Feed; sight*	Cool and supply lube oil	Local gravity fed reservoir of <5 gallons. sight feed oil lubricators Oil cup,LO injector
4a	Rotor Armature	Provide ferromagnetic concentrati	
4c1	Rotor Brushes (DC) *Brushes & Commutator Ring*	Transmit excitation current to rotor	Brush condition is the key consideration that controls the task interval. Wear rates will be very dependent on the accumulated run time. Continuously running motors should have brush inspections at six month intervals unless operating history indicates otherwise. Standby motors could be inspected at 4 year intervals provided they are run or tested occasionally to prevent oxidation of the commutator / brush interface. Operating history is crucial to finding the appropriate intervals.
4c	Rotor Commutator (DC)	Convey current to rotor changing f	
4d	Rotor Shaft	Provide magnetic torque excitation	
4b	Rotor Windings (DC)	Develop rotor magnetic torque for l	Motor Performance Testing should be performed at every other outage, at 3 years, but only for critical motors with power above 20 HP. Performed at all for critical motors, the Motor Performance Testing interval should be 3 to 5 years.
7	Space Heaters	Keep motor winding temperature a	

FIG.23E

2a	Stator - Windings	Structurally constrain stator windin	For V3.0 this task has been added at the suggestion EPRI Maintenance and Diagnostic Center, which also recommends that the task be performed annually for non-critical motors. In the case of standby motors, thermography should be performed after the motor has been running at rated speed for four hours in order to reach a stable operating temperature and hence give valid measurements. When thermocouples or RTDs are installed, direct bearing temperature indication is likely to be monitored frequently, and vibration monitoring provides an independent indication of bearing wear.

Conductor; Windings & Core

Work Orders

	Workscope	Summary	
1	Bridge Test DC MOTOR Detects high resistance electrical connections.	This task has been changed in Version 3.1 to focus on a bridge measurement of the resistance of connections and windings. The Bridge Test is capable of an accurate measurement of the resistance of windings, feeder cables, and motor leads. Winding to winding shorts can be detected as well as poor connections.	3 A (annual)
2	Check LO reservor DC MOTOR Checks intemediate interval motor checks		4 M (month)
3	Maintain Bushes DC MOTOR BRUS Inspects the brushes and commutator.	Brush Maintenance is an inspection of the brushes and commutator. A worn, corroded, or loose brush holder or commutator, is likely to be revealed by erratic operation and excessive sparking. To some degree, contaminated or degraded insulation may also be observable.	6 M (month)
4	Maintain DC DC MOTOR Long term maintenance activity before replacement		10 A (annual)
5	Monitor Acoustics DC MOTOR Identifies grease-related bearing wear and other rotating component problems.	Acoustic monitoring should be effective for addressing some causes of wear in bearings of all types, especially those caused by a lack of grease, or an excess of grease. However, industry experience with this technology is limited, suggesting that information in the database on this technology may be subject to change.	3 M (month)

FIG.23F

6	Operations Rounds DC MOTOR Identifies visible grease leakage, and air flow blockages.	1 SH (shift)	Focus on visible grease leakage, either from worn bearing seals, failed gaskets, or from the use of excessive grease. Other grease related problems such as degraded or insufficient grease, or the use of an incorrect type of grease, may also be observable. External visual inspection is also effective for detecting blocked air inlets. Damaged junction boxes, conduits, or seal flex might also be visible. Failed banding will usually be detectable during the inspection by the audible noise it produces. Improper length or position of brushes and excessive sparking between brushes and commutator are not generally observable without removing an inspection plate. Consequently these aspects of inspection are included in the brush maintenance task. The inspection also includes general observation for loose, missing, or damaged parts, and listening for unusual noises or vibrations, e.g. from mechanical interference between armature and stator.
7	Sys Engr Wlkdwn DC MOTOR Visual inspection indicates grease leakage and air flow blockages.	3 M (month)	This inspection focuses mainly on visible indications of leakage of grease, either from worn bearing seals, failed gaskets, or from the use of excessive grease. Other grease related problems such as degraded or insufficient grease, or the use of an incorrect type of grease, may also be observable. External visual inspection is also effective for detecting blocked air inlets. Damaged junction boxes, conduits, or seal flex might also be visible. Failed banding will usually be detectable during the inspection by the audible noise it produces. Improper length or position of brushes and excessive sparking between brushes and commutator are not generally observable without removing an inspection plate. Consequently these aspects of inspection are included in the brush maintenance task. The inspection also includes general observation for loose, missing, or damaged parts, and listening for unusual noises or vibrations, e.g. from mechanical interference between armature and stator.
8	Test Performance DC MOTOR Ensures that motor electrical characteristics are within specifications, diagnosing many problems.	3 A (annual)	Motor Performance Testing addresses a wide range of degraded electrical conditions. The best procedures and testing equipment provide information about motor performance as well as motor condition.
9	Thermography DC MOTOR Detects exposed electrical connection overheating, bearing overheating, and air passage pluggage.	6 M (month)	The main application of thermography is to provide indication of the condition of exposed electrical connections, and to compliment other indications of bearing wear. Thermography plays a backup role when bearing temperature is directly measured by in-situ RTDs or thermocouples. Other indications of bearing wear are oil and vibration analysis. Thermography can usually only give an indication of increased temperatures in the general region of the bearing casing, where this is accessible. Additionally, thermography can detect clogged air passages and screens.
10	Unassigned PM Tasks Do not delete this placeholder record.	0	

FIG.23G

11	Vibration Monitor DC MOTOR	3 M (month)
	Identifies rotating component bearing wear and rotor unbalance.	Vibration monitoring is very effective for addressing all the causes of wear in anti-friction bearings. Additionally, vibration monitoring addresses all causes of failures originating in the shaft, all causes of failures originating in the armature, and a worn or loose commutator. Cracks, weld failures, and deformation in the frame, enclosure and mounting, soft foot, and other deformation or misalignment causing or caused by failure of machine fits, are also likely to result in detectable vibration.

Work Orders (workscope)

	Task	Part	Failure
1	Vibration Monitor DC MOTOR		3 M (month)
	1 Monitor vibration	Frame, Enclosure, & Mo	Soft foot
	2	Stator - Windings	Loose blocking and bracing
2	Bridge Test DC MOTOR		3 A (annual)
	1 Perform megger test	Rotor Windings (DC)	Insulation breakdown
	2 Perform Bridge phase balance test	Stator - Windings	Insulation degradation
3	Sys Engr Wlkdwn DC MOTOR		3 M (month)
	1 Check bearing temperature	Bearing Lubrication Oil	Inadequate lubricant film
	2 Monitor vibration	Rotor Shaft	Shaft cracking
	3 Trend vibration	Rotor Shaft	Journal & coupling wear
4	Maintain Bushes DC MOTOR BRUSHES		6 M (month)
	1 Inspect brushes	Rotor Commutator (DC)	Worn /galling
	2 Replace brushes	Rotor Commutator (DC)	Worn /galling
5	Thermography DC MOTOR		6 M (month)
	1 Perform thermographic survey	Stator - Windings	Insulation degradation
6	Test Performance DC MOTOR		3 A (annual)
	1 Perform megger test	Feeder Cables and Moto	Insulation cracking
	2 Test low oil pressure lamp "on"	Instrumentation	Lube oil pressure low
7	Monitor Acoustics DC MOTOR		3 M (month)
	1 Check temperature	Bearing Seals	Softened wear, temperature
	2 Monitor vibration (hand held)	Bearings: Journal	Wear
8	Operations Rounds DC MOTOR		1 SH (shift)
	1 Clean motor screen	Air Inlet Openings	Clogged air passages /scree
	2 Inspect motor inlet screens for pluggage	Air Inlet Openings	Clogged air passages /scree
	3 Check leakage	Bearing Seals	Wear aging
	4 Monitor vibration	Bearings: Antifriction	Wear rough
	5 Monitor accoustically	Bearings: Journal	Wear rough
	6 Inspect inlet passages for plugagge	Fan & Cooling Air Filter	Clogged air passages /scree
	7 Change inlet air filters	Fan & Cooling Air Filter	Clogged air passages /scree
	8 Check inlet air filter DP	Fan & Cooling Air Filter	Clogged air passages /scree
	9 Monitor temperature alarms	Frame, Enclosure, & Mo	Clogged air passages /scree
	10 Check lubricator sight glass oil level	Lubrication Supply	Low lubricator level

FIG.23H

	11	Monitor vibration (hand held)	Rotor Armature	Fatigue
	12	Inspect visually	Rotor Commutator (DC)	Brush holder vibration/Wor
	13		Rotor Commutator (DC)	Worn or damaged
	14	Monitor accoustically	Rotor Shaft	Journal & coupling wear
	15	Monitor vibration	Rotor Windings (DC)	Insulation softening
	16	Check heater "ON" lights	Space Heaters	Open element
	17	Monitor accoustically	Stator - Windings	Loose blocking and bracing
9		Check LO reservor DC MOTOR		4 M (month)
	1	Sample lube oil	Bearing Lubrication Oil	Dirty-dissolved metal/oxida
	2		Bearing Lubrication Oil	Wear particles excessive
	3	Visually check lube oil	Bearings: Journal	Wear erosion
	4	Check lube oil level	Instrumentation	Lube oil level low/high faile
	5	Replenish lube oil	Lubrication Supply	Low lubricator level
	6	Check oil feed visually	Lubrication Supply	Loose feed tube
	7	Sample lube oil	Rotor Shaft	Wear (Journal & coupling a
10		Maintain DC DC MOTOR		10 A (annual)
	1	Check temperature sensors "on:	Instrumentation	Winding temperature loop f
	2	Check vibration sensor loop "on"	Instrumentation	Vibration sensor loop failur
	3	Check temperature sensors "on"	Instrumentation	Winding temperature sensor
	4	Inspect visually	Stator - Windings	Surge ring support bracket c
	5	Coat with Glyptol	Stator - Windings	End turn fatigue
	6	Perform Hi-pot DC resistance test	Stator - Windings	Insulation degradation

Authorties

Application	Tag(s)	Component Name		SYSTEM	
MOT	MOT-1	Motor - Direct Current		39	38870 ☑
Applications/Users					
	MTR 24-2	22 CW PMP	US Motors	CW	Circ Wat
	MTR 24-2	22 CW PMP	0		
	MTR 23-3	21 CW PMP	0		
	MTR 14-8	12 CW PMP	0		
	MTR 13-10	11 CW PMP	0		

FIG.23I

Template	PUMP-2	45

Pump - Positive Dispacement

Type	PUMP	Manufacturer	Vickers
Subtype	HPD		
Details			
Component Background			

Type	Subtype	No.	Name
PUMP	HPD	PUMP-2	Pump - Positive Displace
Manuf	Model	Owner	Admin
Vickers	45		

Brief

Pump - Positive Displacement

Complete Description

Multiple cylinder variable stroke pump with wobbler (wobble plate) control. Alternatively variable speed drive.

Scope

The expert panel typical positive displacement pump has:
· Pump, power end and fluid cylinder
· Suction Stabilizer
· Discharge Dampener
· Pump coupling
· Pump gear reducer

Reference/Open Items

1. "Centrifugal and Positive Displacement Charging Pump Maintenance Guide", EPRI (NMAC) TR-107252, October 1997,
2. NRC Information Notice 94-29, "Charging Pump Trip During a Loss-of-Coolant Event caused by Low Suction Pressure".
3. ASME OM Code-1995, "Code for Operation and Maintenance of Nuclear Power Plants", Subsection ISTB, Part 6 - "Inservice Testing of Pumps in Light-Water Reactor Plants".

Additional Basis Information

Expert-identified common dominant failure location/mechanisms:
· Packing leaks
· Damaged valve assemblies
· Damaged oil delivery components
· Cracked fluid cylinders

Equipment Name

· Pump, power end and fluid cylinder
· Suction Stabilizer
· Discharge Dampener
· Pump coupling
· Pump gear reducer
· Oil cooler heat exchanger
· Oil filters, if present
· Packing coolant/lubrication piping and supply tank

FIG.24A

Functions/Failures

Rank	Component Function(s)/Failures	Consequences	Degree
1	Provide high pressure water (fluid) efficiently Fails to provide any high pressure water (fluid)	Fails to control flow	Complete
2	Fails to contain high pressure water (fluid) efficiently	Vibrates excessively	Partial
3	Fails to contain high pressure water (fluid)	Leaks	Partial
4	Fails to provide any high pressure water (fluid)	Fails to deliver flow	Complete
5		Bound elements	Complete
6	Fails to provide high pressure water (fluid) at flow efficiently	Fails to deliver flow at pressure	Partial
7	Provide high pressure water flow status Fails to provide high pressure water flow status	Failed bearing/pressure sensors	Partial

Parts

No.	Part/*Alternate Name*	Functions	Notes
1a	Air Filter	Removes grit from air causing met	
1	Body Housing	Support internal parts retaining flui	The recommended interval for Performance Monitoring is 3 months. Even more frequent performance monitoring (i.e. weekly) would be needed to have a good chance of completely avoiding valve degradation. Because of the possibility of rapid valve degradation, this task may not avoid the necessity for taking a mid-cycle outage to repair the valves, when dependent upon a single pump, regardless of the interval at which it is performed. After refurbishment a typical value of efficiency is 95%, whereas valve replacement is indicated when the efficiency has fallen to around 87% (at least for Union model QX-300 Quintuplex).

FIG.24B

3c1	Coupling	Connect pump load transmitting dr	Task should be moderately effective because the frequencies differ from pump vibrations which would otherwise predominate. This task mainly addresses the condition of couplings. The intervals are not directly determined by the failure mode data but many random mechanisms are addressed. Continuously operating critical pumps are recommended to have a coupling inspection at 2 years regardless of whether they run continuously or are alternated. Vibration monitoring will not give useful information on alignment or coupling wear because of the high intrinsic vibration levels with these pumps. Thermography would provide indication of a coupling running hot, but was not thought to be sufficiently applicable and cost-effective for inclusion in the PM program as a regularly scheduled task. This task is focused entirely on inspection of the coupling. The task interval is not strongly determined by the failure mode data.
	Flex, Flanged or Gear		
2	Drive Mechanism Geareducer	Connect motor/prime mover to co	Experts recommended oil analysis every six months for continuously running or alternated critical pumps. This assumes that analysis and evaluation are carried out in timely manner.
	Main Bull/Pinions		
5	Fluid Cylinder	Compression or combustion locati	Degradation mechanisms and time scales suggest that the Fluid Cylinder Inspection is likely to be required after 1 year of operation. The deterioration rate of inlet and outlet valves is sufficiently rapid after onset, and the predictive capability of Performance Monitoring is sufficiently weak, that positive displacement pump outages in order to perform the Fluid Cylinder Inspection, may not be avoidable between refueling cycles unless a redundant pump is available. When a redundant pump is not available consideration should be given to scheduling the Fluid Cylinder Inspection as a time-directed task with an interval less than 6 years. Carrying out the Performance Monitoring task more frequently (perhaps weekly) does not avoid the problem. If good performance of packing, valves, and oil seals enables the Fluid Cylinder Inspection to be done only every 3 to 6 years, the valves, oil seals, plunger, and oil pump (if external) should be replaced regardless of condition, especially if a redundant pump is not available.
	Water or Oil, typically		
6	Fluid End Gaskets & Seals	Seal pressure components	
5a	Inlet and Outlet Valves & Seats	Isolate pump for maintenance	

FIG.24C

9	Loading Controls	Control loading	Task is performed at least once per day.
2a	Main Bearings	Rotate closure and trip mechanis	Task provides assurance that the Power End Inspection can be reached at 6 years without undue wear on the above components. The Expert Panel thought that a 2 year interval for the Internal Visual Inspection would provide this assurance in a cost-effective manner.
	Crosshead bearings		
3a	Main Shaft (Engine Driven)	Transmit torque	
3	Motor/Power End	Drive motor-end	Task should be moderately effective whenever a direct view can be obtained. This task is focused on the detection of hot spots. The intervals are not directly determined by the failure mode data but many random mechanisms are addressed.
4d	Oil Reservoir Breather	Allow air equalization for pressure	
4	Oil & Reservioir	Supply clean oil to demand	A task interval of 6 years adequately addresses the above failure mechanisms. Oil Sampling and the Internal Visual Inspection provide reasonable assurance of avoiding failures from random effects at earlier times.
4c	Oil (Fluid) Cooler	Cool clean oil supply	
4b	Oil Filter	Clean oil particulates	Filter replacement is recommended as a scheduled task at 6 months for continuously operating or alternated pumps.
4a	Oil Pump & Lubricator	Lubricate pump bearings & equip	
	Grease charging lubricator, box lubricator		
5b	Packing	Seal Pneumatic air in cylinder	
5b2	Packing Seal Water	Seal bearing seal water in cylinde	
2b	Pinion Shaft Bearings	Align pinion driver stage	
3b	Power End Gaskets & Seals	Seal power end of equipment	
6b	Relief Valve Ports, O-ring seal I	Provide overpressure relief path	
5b1	Stuffing Box	Isolate process fluid from environ	
5d	Suction/Discharge Dampeners	Dampen pressure pulsation shock	Most installations have discharge dampener; many suction, too.
	Accumulators, Stabalizers, Pulsation Dampeners		
5c	Valves, Plunger and Seals	Operate compressor stroke seque	

Work Orders

FIG.24D

	Workscope	Summary	
1	Coupling Inspection COUPLING		2 A (annual)
	Inspects coupling for seal failure and noise. Can be performed as rounds/performance monitoring.	As the name implies this task is focused entirely on inspection for lubrication leaks and wear of the flexible grid type and geared type of pump/motor couplings, and on distortion or cracking of the shims on the shim pack types.	
2	Fluid Cylinder Inspection PUMP		4 A (annual)
	Inspects cylinder head check valves, oil seal leaks, packing leaks, and cracked fluid cylinders, and to inspect the packing cooling/lubricating system integrity.	The Fluid Cylinder Inspection provides an opportunity to inspect and repair cylinder head check valves, leaks from oil seals, leaks from packing, and cracked fluid cylinders, and to inspect the integrity of the packing cooling/lubricating system. This is an on-condition task which may be triggered by observation of leaks during operator rounds, by audible noise and results of performance monitoring with respect to worn or broken valves, and by leakage, performance monitoring, or loss of fluid inventory in the case of a cracked fluid cylinder.	
3	Inter Visual Inspect PUMP		2 A (annual)
	Assess oil pump drive chain and sprockets, thrust bearing, main gear and pinion, and visible gaskets. Major work for continuously running pumps.	Internal Visual Inspection is an internal inspection performed when the power end large inspection cover has been removed. The main objectives of this task are to assess the condition of the oil pump drive chain and sprockets, and the tightness of the oil pump mounting bracket in a pressure lubricated system, as well as to assess the condition of the thrust bearing, main gear and pinion, and gaskets that are visible.	
4	Oil Analysis PUMP		6 M (month)
	Detect wear particles or other contaminants in the oil, and measure oil quality.	Oil analysis is focused on processes that result in wear particles or other contaminants entering the oil and on degradation of the lubricating properties of the oil. This primarily addresses wear and scoring of the cross-head to cross-head surfaces and asymmetric wear of the main gear and pinion teeth, as well as deterioration of bearing oil seals, and wear of the oil pump, drive chain and sprockets in a pressure lubricated system. Wear of the crosshead pin and bearing, main crankshaft bearings, connecting rod bearings, pinion shaft and bearing, and thrust bearing, can also be detected.	
5	Oil Filter Replacement PUMP/MOTO		6 M (month)
	Focuses on oil filter clogging and lubricant contamination.	This task focuses entirely on the condition of the lubrication system. Items to observe are a clogged oil filter and contamination of the lubricant.	
6	Operations Rounds PUMP		1 SH (shift)
	Observe leaks, unusual noise, loose, missing, or damaged components. For pumps in daily use (like charging pumps) observation is effective for many random degradation mechanisms.	Observe leaks of water or oil, unusual noises, and obviously loose, missing, or damaged fasteners and hardware. It also provides an opportunity to verify that the oil delivery system and packing cooling system are operating within normal limits.	
7	Performance Monitor PUMP		3 M (month)
	Inlet (suction)/ outlet (discharge) valve cracking and wear, valve seats and springs, and fluid cylinder cracking.	Performance Monitoring mainly addresses cracking and wear of the inlet (suction) and outlet (discharge) valves, valve seats and springs, and cracking of the fluid cylinder. Worn valve guides may also be detected but these are only likely to be common occurrences in specific applications.	

FIG.24E

8	Power End/Frame Inspect MOTOR/E		6 A (annual)
	Major pump power end work.	This task focuses principally on the condition of the oil delivery system: oil pump, drive chain, and sprockets in a pressure lubricated system, or the gear driven external oil pump. Other important components addressed are the crosshead, including the crosshead to stub fit, bearings, crankshaft, gears, gaskets, and the oil heat exchanger, if present..	
9	Thermography PUMP/MOTOR		6 M (month)
	Detects hot spots, addressing many mechanisms.	Thermography will detect hot spots which cause cylinder damage and degradation of packing cooling.	
10	Unassigned PM Tasks		0
	Do not delete this placeholder record.		
11	Vibrtn Analysis PUMP/MOTOR		6 M (month)
	Addresses coupling condition.	Vibration Analysis can be effective for detecting distorted and cracked shims in couplings, grid type coupling wear, and gear type coupling degradation.	

Work Orders (workscope)

	Task	Part	Failure
1	Oil Analysis PUMP		6 M (month)
1	Sample fluid for water	Oil (Fluid) Cooler	Tube roll/tube leaks
2	Sample cooling water for oil contamination	Oil (Fluid) Cooler	Tube roll/tube leaks
2	Performance Monitor PUMP		3 M (month)
1	Monitor noise (accoustically)	Coupling	Lube leakage
2	Check slipping noise	Coupling	Wear
3	Check discharge pressure	Fluid Cylinder	Scored liner/bore taper
4	Check crankcase housing contamination	Inlet and Outlet Valves	Valve guide wear
5	Trend discharge pressure	Inlet and Outlet Valves	Valve seat wear
6	Test cooler heat transfer	Oil (Fluid) Cooler	Fouled tubes
7	Check pump output	Oil Pump & Lubricator	Pump cylinder
8	Check discharge fluid contamination	Valves, Plunger and Sea	Fluid Seal Leakage
9	Trend discharge pressure	Valves, Plunger and Sea	Valve seat wear
3	Oil Filter Replacement PUMP/MOTOR		6 M (month)
1	Change breather	Oil Reservoir Breather	Plugs
2	Replace filter	Oil Filter	Plugged
3	Replace packing	Stuffing Box	Packing set
4	Inter Visual Inspect PUMP		2 A (annual)
1	Replace coupling	Coupling	Wear
2	Replace/rework liner	Fluid Cylinder	Scored liner/bore taper
3	Calibrate control loop	Loading Controls	Fails to control
4	Lubricate bearings	Motor/Power End	Motor bearings fail
5	Replace motor	Motor/Power End	Motor failure
6	Drain reservoir	Oil & Reservioir	Oil sludge

FIG.24F

	7	Inspect cooler	Oil (Fluid) Cooler	Tube roll/tube leaks
	8	Replace packing	Packing	Wear
	9	Replace bearings	Pinion Shaft Bearings	Bearing failure
	10	Test relief setpoint	Relief Valve Ports, O-ri	Setpoint drift out-of-spec
	11	Check accumulator gas precharge	Suction/Discharge Dam	Lose precharge
	12	Check accumulator drains for liquid	Suction/Discharge Dam	Ruptured bladder
	13	Replace seals	Valves, Plunger and Sea	Fluid Seal Leakage
5	Fluid Cylinder Inspection PUMP			4 A (annual)
	1	Calibrate relief lift setpoint	Relief Valve Ports, O-ri	Setpoint drift out-of-spec
	2	Check temperature alarm	Valves, Plunger and Sea	Spring cracking
6	Power End/Frame Inspect MOTOR/ENGINE			6 A (annual)
	1	Change breather	Air Filter	Plugged housing breathing
	2	NDE Shaft	Main Shaft (Engine Driv	Fatigue cracking
	3	Replace gaskets, O-rings and other soft parts	Power End Gaskets & S	Compression set
7	Operations Rounds PUMP			1 SH (shift)
	1	Check sealed couplings for leakage	Coupling	Lube leakage
	2	Monitor noise	Coupling	Flex failure
	3	Check discharge pressure	Fluid Cylinder	Low compression
	4	Check temperature alarm	Main Bearings	Inadequate Lube
	5	Monitor temperature alarm	Main Bearings	Inadequate Lube
	6	Check lube flow	Main Bearings	Inadequate Lube
	7	Monitor temperature alarms	Motor/Power End	Motor bearings fail
	8		Motor/Power End	Motor bearings fail
	9	Check lube oil level	Oil & Reservioir	Low oil level
	10	Check lubricator operation	Oil Pump & Lubricator	Lubricator fails to advance
	11	Check shaft leakage	Packing	Wear
	12	Check seal water flow	Packing Seal Water	Inadequate flow
	13	Monitor accoustically	Valves, Plunger and Sea	Spring cracking
	14	Monitor temperature alarms	Valves, Plunger and Sea	Spring cracking
8	Thermography PUMP/MOTOR			6 M (month)
	1	Perform thermographic survey	Fluid End Gaskets & Se	Internal leakage
	2	Perform thermogrphic survey	Main Bearings	Inadequate Lube
9	Vibrtn Analysis PUMP/MOTOR			6 M (month)
	1	Check vibration	Body Housing	Loose grout foundation
	2	Vibration monitoring	Drive Mechanism Geare	Geartooth failure
	3	Monitor vibration	Main Bearings	Excessive wear
	4	Vibration monitoring	Pinion Shaft Bearings	Bearing failure
	5	Check flow accoustically	Suction/Discharge Dam	Lose precharge

Authorties

FIG.24G

Application Tag(s)		Component Name		SYSTEM	
PUMP	PUMP-2	Pump - Positive Displacement		45	139188 ☑
Applications/Users					
	245-041	21 CHG PMP	Vickers	VC	Chemica
	245-043	23 CHG PMP	0		
	245-042	22 CHG PMP	0		
	245-041	21 CHG PMP	0		
	145-043	13 CHG PMP	0		
	145-042	12 CHG PMP	0		
	145-041	11 CHG PMP	0		

FIG.24H

RELIABILITY TOOLS FOR COMPLEX SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/731,324, filed on Oct. 28, 2005, the entire disclosure of which is hereby incorporated herein by reference.

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FIELD

The present invention is related to the development and organization of maintenance programs or tools for complex systems.

BACKGROUND

The maintenance of production systems is important in order to ensure production efficiency and safety. In connection with complex production systems, such as nuclear power plants, scheduled maintenance and repair procedures, usually implemented in connection with a computerized maintenance management system (CMMS), are often voluminous and unwieldy. In addition, procedures for responding to failures within a complex plant prepared in anticipation of certain failures (e.g., equipment degradation), are often performed without an appreciation of the impact of the failure on the stated safety, operating or cost performance goals of the plant. As a result, the preventive and corrective maintenance procedures associated with complex plants using conventional computerized maintenance management methods have been inefficient and/or ineffective.

The traditional approach to performing maintenance and responding to failures in complex plants or systems has been to apply maintenance and repair procedures without an appreciation of the context in which the maintenance or repair will occur. For example, a typical system may address a failure of a valve (e.g. a leak) by calling for replacement of that valve. However, there is usually little or no concern for the context in which the component (here a valve) operates. For instance, a valve may perform an important safety function or may control the flow of a dangerous substance, and may therefore be critical to the safe operation of the plant. Alternatively, it may be part of the water supply system used to wash the plant floors, and therefore a leak in the valve is trivial. However, because systems have not generally considered the context in which systems and components in a plant function, the limited maintenance and repair resources of a plant may quickly become overwhelmed by long lists of tasks, many of which may be relatively unimportant to the safe or efficient operation of the plant.

Another aspect of maintaining complex systems is tracking the changes that inevitably occur to the system over time, and making appropriate adjustments to maintenance and repair procedures affected by those changes. For example, a component in a plant may be replaced by a component that performs an identical function, but that has a very different design requiring different maintenance procedures. Conventional systems have typically not accommodated or required notes or the creation of historical records for justifying and documenting such changes. Therefore, changed maintenance or repair procedures may not be reflected by the computerized maintenance management system, or unjustified changes may be questioned by maintenance personnel, resulting in inappropriate maintenance or repair.

In order to efficiently allow for a maintenance program to model a complex system, it is useful to provide ready-made component descriptions that can be included in the overall system model. Although such descriptions have been available, they have not addressed adjustments or modifications that are necessitated by the context in which the component functions within the plant. In general, the context of a component is related to the function that the component provides in relation to the system in which the component is included, where the system defines, at least in part, the stress, environment, risk and service demand placed on the component. As a result, the maintenance and repair procedures that are associated with the component descriptions fail to take into account the actual operating conditions and the ramifications of failure or particular failure modes of the associated components. This again can result in unnecessary or inappropriate maintenance and repair procedures for components in a plant. In addition, where modifications to models of plant components are necessary, conventional computerized maintenance management systems have been unable to efficiently identify symmetries in the subject plant in order to facilitate the appropriate reuse of customized models of plant components. Conventional management systems have also been of limited assistance in determining what spares should be stocked, and what spares do not need to be stocked, in order to facilitate the uninterrupted operation of a plant, without maintaining an unreasonable inventory of spares.

SUMMARY

Embodiments of the present invention are directed to solving these and other problems and disadvantages of the prior art. In accordance with embodiments of the present invention, a master equipment list provides a list of complex plant components. A number of systems included in the plant are identified, and each of the components included in the master equipment list is assigned to at least one of the identified systems. A template or model is associated with at least some of the components. The template or model includes or references maintenance and repair procedures associated with the modeled component.

In accordance with embodiments of the present invention, the identification of systems within a complex plant comprises an identification of the criticality of each system to the overall plant. The identification of a system's criticality with respect to the complex plant can comprise identifying the safety, production operations or cost effects of a failure of the system. Furthermore, the criticality of the systems within the complex plant can be ranked. For example, a system that is critical to the safe operation of a plant is more critical than a system that is critical to the production operations of the plant, which is in turn more critical than a system that is critical to the cost effective operation of the plant. In accordance with embodiments of the present invention, the identification of the criticality of a system provides a context for that system within the complex plant. This context can then be used to identify critical components, and to assist in determining appropriate maintenance and repair procedures for

components within each system. In addition, this context can be used to identify critical component parts in connection with selecting spare parts that are stocked by the complex plant.

Critical components may comprise components that have a significant effect on safety, operations (production), or cost objectives should they fail. A critical part is a part of a critical component that causes the critical component to fail if the part fails. In determining whether a component is a critical component, consideration may be given to the presence of redundant components. In accordance with embodiments of the present invention, only those components identified as critical components are associated with a template. Accordingly, embodiments of the present invention recognize that an efficient and effective maintenance and repair system, hereinafter referred to as a reliability system, can be developed through intelligently excluding components that are non-critical.

A library of component templates is available for use by system operators in order to develop a model of at least some of the components in the complex plant. In particular, a user may retrieve a library template that has some correspondence to a component to be modeled. The user may then associate the library template with the particular component being modeled, creating an applied template. In addition, the user may modify the library template in order to more closely reflect the component being modified to create the applied template for that component.

In accordance with embodiments of the present invention, symmetry may be applied in order to assist in the creation of a plant model. The application of symmetry may comprise identifying groups of components within a system or within a complex plant that perform like functions. Once such groups have been identified, application templates developed for one of the groups can be used to model other of the groups, or as the basis for a model of other of the groups if modifications to the model are desired for those other groups.

Additional features and advantages of embodiments of the present invention will become more readily apparent from the following description, particularly in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**, is a block diagram depicting the organization of an exemplary complex plant in accordance with embodiments of the present invention;

FIG. **2** is a block diagram of aspects of a reliability system in accordance with embodiments of the present invention;

FIG. **3** is a block diagram of components of a reliability system platform in accordance with embodiments of the present invention;

FIG. **4** is a flow diagram illustrating general aspects of the operation of a reliability system in accordance with embodiments of the present invention;

FIG. **5** is a flow diagram illustrating aspects of the creation of applied templates in connection with a reliability system in accordance with embodiments of the present invention;

FIG. **6** is a flow diagram illustrating other aspects of the creation of applied templates in connection with a reliability system in accordance with embodiments of the present invention;

FIG. **7** is a flow diagram illustrating aspects of the operation of a reliability system in connection with an operating complex plant in accordance with embodiments of the present invention;

FIG. **8** is a flow diagram illustrating the modification of a reliability system in accordance with embodiments of the present invention;

FIG. **9** is a flow diagram illustrating an example process for assigning tasks to workscopes in accordance with embodiments of the present invention;

FIG. **10** is a flow diagram illustrating a process for identifying spare parts that should be stocked in accordance with embodiments of the present invention;

FIG. **11** is a screen shot illustrating a list of example library templates displayed to a user and available for selection in accordance with embodiments of the present invention;

FIG. **12** is a screen shot illustrating aspects of an example library template displayed to a user in accordance with embodiments of the present invention;

FIG. **13** is a screen shot illustrating a tree view of example applied templates in accordance with embodiments of the present invention;

FIG. **14** is a screen shot illustrating a tree view of parts and a display of part failures of an example component in accordance with embodiments of the present invention;

FIG. **15** is a screen shot illustrating a tree view of parts and preventive maintenance tasks in accordance with embodiments of the present invention;

FIG. **16** is a screen shot illustrating a tree view of parts and details of an example preventive maintenance task in accordance with embodiments of the present invention;

FIG. **17** is a screen shot illustrating a display that may be provided to a user in connection with the selection of a workscope in accordance with embodiments of the present invention;

FIG. **18** is a screen shot illustrating a tree view of component parts, failure modes and maintenance tasks;

FIG. **19** is a screen shot illustrating a view of failures and parts;

FIG. **20** is a screen shot illustrating a work order scope;

FIG. **21** is a screen shot illustrating preventive maintenance tasks and associated bases;

FIGS. **22**A-**22**L illustrate an example library template for a component;

FIGS. **23**A-**23**I illustrate an example template for another component; and

FIGS. **24**A-**24**H illustrate an example template for another example component.

DESCRIPTION

Embodiments of the present invention are directed to the development and operation of reliability systems for the maintenance and repair of complex plants. As illustrated in FIG. **1**, a complex plant **100** may be modeled as a collection or combination of a number of systems **104**. As used herein, a complex plant is any system, production facility or plant that can be divided into a number of systems that each include one or more components.

In accordance with embodiments of the present invention, each of the systems **104** within the complex plant **100** is associated with a function and/or a context. In particular, the systems **104** within a complex plant **100** are the tangible assemblies that allow functions to be provided. Examples of different functions for systems **104** that can result in the assignment of different contexts to systems **104** include functions that impact the safety of the complex plant, functions that impact the operations (production) of the complex plant, and functions that impact the cost efficiency of the complex plant. In addition, each system **104** is comprised of a number of components **108**. Accordingly, systems **104** may be

defined as a set of components **108** that together provide an identified function within the complex plant **100**. Each component of a system **104** may be included in a component list **112** for that system **104**. In accordance with embodiments of the present invention, the component lists **112** may comprise or be derived from a master equipment list.

With reference to FIG. **2**, a reliability or maintenance tool, referred to herein as a reliability system **200** in accordance with embodiments of the present invention may include an administrative program **204** that receives or has access to a number of inputs, including data sources or data repositories. These inputs may be in the form of relational tables, look-up tables or lists (hereinafter referred to as tables). These tables can include a template library **208**, a set of applied templates **212**, a master equipment list (MEL) **216**, risk/symmetry **218** assignments, considerations based on accumulated operator experience **220**, and various look-up tables **224**. Other tables that can be included in the reliability system **200** include a locked set of application templates **228**, a locked master equipment list **230**, metadata **232**, system groupings **236**, miscellaneous ad hoc groupings **240** and upload generator or table generator reconciler for preparing files in the format required by other systems that can make use of or present information from the reliability system **200**.

The administrative program **204** generally functions to provide a graphic user interface (GUI) to a user, to organize and control the use and interaction of the various inputs, and to generate reports that compile information that can be presented in formats specified by the user. Accordingly, the administrative program **204** may comprise instructions or programming code executed by, for example, a general purpose computer. The administrative program **204** may also incorporate various of the inputs or other functions. For example, the administrative program **204** may incorporate a processed information report function **244**, a risk viewer **246**, and a user interface **248**. In accordance with embodiments of the reliability system **200**, the administrative program **204** functions are split between functions performed in connection with instructions executed by a server computer and functions performed in connection with instructions executed by a client computer. For example, a server management program part or server administrative program part of the administrative program **204** may run on the server computer, to ensure that clients are properly authorized to access or operate as part of the reliability system **200**, and perform error recovery. The client computer may, for example, run a client administrative program comprising technical management functions of the administrative program, such as entering data, selecting and modifying templates, generating work orders, providing a user interface and other functions.

The template library **208** may comprise a collection or database of library templates **252** that can be used as models or as the basis of models for various components **112** included in a plant **100**. Each library template **252** generally includes a description and/or listing of the parts of the component **112** modeled by the library template **252**. More particularly, each library template **252** may comprise a description and/or listing of the critical parts of the component modeled by the library template **252**. In addition, each library template **252** may include information related to failure modes of the modeled component **112**, and typical approved or manufacturer recommended maintenance procedures and intervals. In accordance with embodiments of the present invention, each library template **252** included in the template library **208** is stored as a read-only copy, to prevent corruption of the library templates **252**.

The set of applied templates **212** may comprise a collection or database of applied templates **256**. As used herein, an applied template **256** is a template that has been selected or customized for use as a model of a component included in a complex plant **100**. Accordingly, an applied template **256** may comprise a template that a user has associated with a component **112** from the master equipment list **216**. Furthermore, an applied template **256** may comprise a copy of a library template **252** that has been associated with a component **112** from the master equipment list **216**. In creating an applied template **256**, a copy of a library template **252** may also be modified to more accurately reflect the particular characteristics or features of the modeled component **112**. The creation of an applied template **256** may also include modifying a copy of a library template **252** to adjust associated maintenance and/or repair procedures and/or intervals as appropriate for the context or criticality of the modeled component **112**. Furthermore, multiple applied templates **256** may be associated with a component **112**. For example, multiple applied templates **256** may be used for a single component **112** when it is desirable to subpartition the component **112** because the component **112** is complex, comprised of a number of replaceable parts, comprised of a number of subsystems, or as otherwise capable of being meaningfully represented by or associated with a number of applied templates **256**. An applied template **256** may also be created without borrowing from an existing library template **252** or applied template **256**. Applied templates **256** may also be modified after their initial creation in order to reflect changes to the associated component **112**, changes to the context or criticality or context of the associated component **112**, or revisions to maintenance and repair procedures for the associated component **112**. In addition, an applied template **256** may be copied for use, either unmodified or with modifications, in connection with another component **112**, that is identified as being identical or similar to the component **112** associated with the copied applied template **256**. In accordance with embodiments of the present invention, an applied template **256** may further comprise a set of elements of relational data stored in other of the tables. Accordingly, multiple components **112** may be associated with the same set of data comprising an applied template **256**, except for data such as a tag number or other information that is unique to a particular component **112**.

The master equipment list (MEL) **216** may comprise a list of all of the components **112** included in a plant **100**. Alternatively, the master equipment list **216** may comprise the components included in systems of a plant that are to be modeled through the creation of application templates **256**. The master equipment list **216** may comprise a list generated during design of the plant **100**, or at some later time, that is downloaded or entered into the reliability system **200**. In addition, the master equipment list **216** may be modified during the life of the plant **100** to track changes in installed systems and/or components.

The master equipment list **216** may also incorporate or be associated with a risk/symmetry table **218**. The risk/symmetry table **218** can be used in connection with identifying the safety, operational and cost effects of a failure of each component **112** within the complex plant **100**. In accordance with embodiments of the present invention, the risk/symmetry table **218** identifies such effects from a consideration of the context in which the component **112** or the system **104** in which the component is included functions. The risk/symmetry table **218** also assists in identifying or maintaining a record of those components **112** of the complex plant **100** that are critical to the functioning of the system **104** of which they are

a part. A component **112** is critical if a failure of that component **112** directly affects the safety, operational or cost performance of the complex plant **100**. In addition the risk/symmetry table **218** may take into account the existence (or not) of redundancies in characterizing the risk or criticality to associate with the failure of a particular component **112**. Where redundancies exist, a component **112** may be considered non-critical. A decision to treat a particular component **112** as non-critical may be recorded in this risk/symmetry table **218**. The identification of symmetries allows one description or template **256** of a replicated component **112** to be used for all of the copies or instances of that component **112**, with or without modifications. Identified symmetries can therefore be recorded in the risk/symmetry map or table **218** to improve the efficiency and user friendliness of the reliability system **200**. In accordance with embodiments of the present invention, every component **112** included in the MEL **216** for a complete plant **100** is included or accounted for in the risk/symmetry table **218**.

In accordance with further embodiments of the present invention, an operator experience considerations table **220** maintains information related to operating experience regarding systems **104** and/or components **112**. Examples of operating experience considerations that may be maintained in the operator experience considerations table **220** include maintenance or repair procedures that are in addition to or are different than manufacturer recommended procedures for particular components **112**. Furthermore, such operator considerations may apply or be limited to particular components **112** that are operated or used in particular contexts or systems **104**. Parts or components that have failed in other complex plants are examples of particular items that can be included in operating experience considerations.

In general, the look-up tables **224** comprise a number of tables describing different aspects of a component **112** represented by a template, including an applied template **256**. Examples of the tables that may be included in the look-up tables **224** include equipment class tables **264**, and maintenance task class tables **268**. Other examples of tables that may be included in the look-up tables **224** include tables of common parts, component or part failure modes, tests, preventive maintenance justifications, cost estimation and industry operating events. By referencing the look-up tables **224** and/or other tables, applied templates **256** can be expressed, at least in part, as a set of elements of relational data. As can be appreciated by one of skill in the art, such a structure can speed data entry and increase database (and therefore reliability system **200**) efficiency, by referencing common data, rather than complete replications of such data.

The locked set of applied templates table **228** allows for versioning of the complex plant **100** model represented through the reliability system **200**. In particular, a set of read only or locked applied templates **260** may be maintained in the locked set of applied templates **228**. As different versions of the complex plant **100** model are developed, they may be stored as different sets of locked applied templates **260** in the locked set of applied templates **228** table, or in other locked sets of applied templates tables **228**.

The locked master equipment list table **230** allows for versioning of the master equipment list used in connection with the development of sets of applied templates **256**, and of sets of locked applied templates **260**. The locked master equipment list table **230** can maintain a number of different master equipment list versions, or different versions can be stored as part of different locked master equipment list tables **230**.

The meta data table **232** generally maintains information related to the classification of tasks, the classification of component types **112**, the classification of system **104** functions and contexts, and/or other information about items or categories of information within the reliability system **200**. Accordingly, the meta data table **232** may serve as a repository for reference information.

The system groupings table **236** maintains information regarding the identification of different functions or systems **104** within the complex plant **100** modeled by the reliability system **200**. Accordingly, the system groupings table **236** may contain lists of components **112** associated with the different systems **104**.

The miscellaneous ad hoc groupings table **240** can be used to maintain user defined groups or assemblies **272** of data. Examples of user defined groups **272** include groups of components **112** comprising additional systems **104** or subsystems that are defined for use in connection with performing maintenance or repair tasks. For instance, a group **272** of components **112** within a tag-out boundary may be defined in connection with creating a list of maintenance and repair tasks that are to be performed while the group **272** of components **112** within the tag-out boundary are offline.

The report generator **244** may comprise an administrative program **204** function that operates to compile records associated with other functions or modules to produce reports for presentation to a user. These reports may comprise reports related to systems **104**, component lists **108**, components **112** or other aspects of a plant **100**. In addition, reports may comprise procedures to be performed by maintenance personnel as part of scheduled maintenance or repairs, the actual or anticipated cost of maintenance work or repairs, and statistics. In accordance with embodiments of the present invention, the report generator **228** is user-configurable, to allow the user to include desired information in a desired format. In addition to supporting the generation of reports in response to queries entered by the user, sophisticated built-in reports can be accessed through buttons and/or drop down menus provided through the user interface **248**. Accordingly, user defined groups **272** or other groupings, for example in the form of reports or tables, may be created or accessed by or in association with the report generator **244**, formatted for implementation tools. A report may be provided to a user by the report generator **244** in various ways. For example, a report may comprise a screen presentation to a user, a hard copy output or a stored file that can be output at a later time.

The risk viewer **246** allows a user to determine or diagnose various perceived or anticipated problems associated with a complex plant **100**. For example, if a noise or other abnormal condition is perceived, the risk viewer **246** allows a user to access information describing the consequences if a component **112** associated with the perceived abnormal condition should fail. Accordingly, the risk viewer **246** can provide or operate in association with diagnostic functions. In accordance with embodiments of the present invention, the risk viewer **246** comprises a specialized set of queries or searches. In accordance with further embodiments of the present invention, the risk viewer **246** may provide output related to the consequences of the failure of a component **112** or other diagnostic information by accessing operating experience considerations **220** or risk information associated with a template **252** and/or **256** for a component **112**.

The user interface **248** may comprise a graphical user interface for receiving instructions and information from and presenting information to a user. In accordance with embodiments of the present invention, the user interface **248** presents information using expandable tree views. In addition, tree

views can speed the application process through presenting information in context and by providing checkboxes. In accordance with further embodiments of the present invention, the user interface **248** presents information in association with drop down menus.

With reference to FIG. **3**, components that may be included as part of a distributed computing system **300** for implementing the disclosed reliability system **200** are illustrated. In particular, the computing system **300** is an example of an arrangement of computer components that may be used in connection with the execution of application programming, such as the administrative program **204**, and the development, operation and storage of a database in accordance with embodiments of the present invention. As illustrated in FIG. **3**, the distributed computing system **300** may comprise a server computer **304** and one or more client computers or workstations **308** interconnected by a network **310**, such as a local area network (LAN) and/or a wide area network (WAN). In accordance with embodiments of the present invention, at least a portion of the network **310** may comprise the Internet.

The server computer **304** may comprise a general purpose computer, and may execute instructions on its processor or processors that implement a server administrative program **312** portion of the administrative program **204**. As an example, the server administrative program **312** may perform the processing necessary in order to respond to information, commands and requests received from a client computer **308**. The server administrative program **312** may also operate to provide time based maintenance task lists or workscopes. Accordingly, the server administrative program **312** may comprise instructions implementing at least some of the report generator **244** functions of the administrative program **204**. In accordance with still other embodiments, the server administrative program **312** may additionally receive realtime information from sensors and instruments included in the complex plant **100**, permitting realtime monitoring and updating in connection with the reliability system **200**. In addition, the server administrative program **312** may operate to support or provide at least part of the user interface **248** portion of the administrative program **204**. The server computer **304** may also include user input/output facilities **314** to allow user operation of the reliability system **200**, and/or configuration of the reliability system **200**.

The client computer **308** may comprise a general purpose computer, and may execute instructions on its processor that implements a client administrative program **316** portion of the administrative program **204**. The client administrative program **316** may implement at least portions of the report generator **244** function of the administrative program **204**. The client administrative function may further comprise the user interface **248**, or portions of the user interface **248**, of the administrative program **204**. In connection with the receipt of instructions and data from a user, and the delivery of reports to the user, the client computer **308** also generally comprises user input/output facilities **320**, such as a keyboard, mouse, monitor, printer and/or other input or output devices.

In addition, the computing system **300** may comprise or be associated with computer storage **324** comprising a database **328** containing the various tables and other information and/or programming maintained as part of the reliability system **200**. The computer storage **324** may be implemented as part of the server computer **304** and/or one or more client computers **308**. The computer storage **324** may also be implemented as a storage subsystem, such as a redundant array of independent disks (RAID) system. The computer storage **324** may be implemented as a storage area network (SAN) or as network storage. Furthermore, the computer storage **324** may be directly interconnected to the network **310**, or interconnected to the network **310** through another component or network node, such as through the server computer **304**.

Aspects of the operation of a reliability system **200** in accordance with embodiments of the present invention are illustrated in FIG. **4**. Initially, a system **104** is selected, and the functions and failures for the selected system **104** are identified (step **404**). The identification of functions and failure modes may include identifying the implications to safety, operations (production) and costs of a failure of the selected system **104**. That is, the criticality of a selected system can be determined. In addition, more than one failure mode may be identified for the selected system **104**. Furthermore, where more than one failure mode is identified, different safety, operations and cost effects can be identified for the system **104**.

The component file or master equipment list (MEL) **216** may then be developed or obtained (step **408**). In general, the master equipment list **216** may comprise a list of those components **112** that are required for or are associated with meeting the functional requirements of the selected system **104**. Development of the master equipment list may therefore comprise performing an inventory of components **112** that have a bearing on the identified function of the selected system **104**. Alternatively, a previously prepared or developed master equipment list **216** may be downloaded to the reliability system **200**, and components from that master equipment list **216** may be associated with the selected system **104**.

At step **412**, a preliminary planning review may be performed. As part of the preliminary planning review, the functions of and boundaries between systems **104** included in the complex plant **100** (or identified for purposed of operation of the reliability system **200**) may be considered together, to ensure adequate coverage of significant aspects of the overall plant **100**. Accordingly, it can be appreciated that steps **404** and **408** may be performed for each system **104** of the plant that are to be included in the model developed as part of the reliability system **200**. Furthermore, it can be appreciated that the process may be performed iteratively, such that the identification of plant systems **104**, the identification of system **104** functions and failure modes, the components **112** included within the identified systems **104**, and/or the allocation of components **112** between systems **104** are revised to accurately reflect complex plant **100** design and/or operation.

After associating components **112** with a system **104**, and preferably after associating components with a number of systems **104**, symmetry groups of components **112** may be identified (step **416**). The identification of symmetry groups may comprise identifying multiple trains or skids consisting of groups of components **112** within a particular system **104** or within the plant **100** that are functionally identical.

At step **420**, critical components may be identified. In accordance with embodiments of the present invention, a critical component is a component **112** that has an impact on a safety, operations or cost function of a related system **104**. In accordance with embodiments of the reliability system **200**, a critical component is one that is associated with a single failure direct function impact. That is, the failure of a critical component has a direct impact on the safety, production operations or cost performance of the complex plant. In determining whether a component **112** is a critical component, consideration may be given to whether the system **104** includes redundant components **112**. Consideration may also be given to whether there are hidden or indirect safety, operational or cost implications associated with the failure of a particular component **112**. If a component **112** is determined to not be critical, it can be excluded from the model of the

complex plant **100** established by the reliability system **200**. The exclusion of non-critical components, in accordance with embodiments of the present invention, is an important aspect to developing a relevant maintenance and repair response, and to developing an efficient model of the complex plant **100**. For example, as many as 60-80% of the components in a typical plant may be considered non-critical, and therefore do not require a model or template in the reliability system **200**, and do not require any scheduled maintenance. Therefore, by identifying and excluding non-critical components, the efficiency of the reliability system **200** and of the complex plant **100** maintenance program can be improved. In accordance with embodiments of the reliability system **200**, a justification or basis may be required in connection with components **112** that are identified as non-critical, for example to provide documentation of decisions to treat certain components as non-critical. A justification or basis for determining that a component **112** is non-critical can be stored in the risk/symmetry table **218** associated with the master equipment list **216** for the complex plant **100**.

For those components **112** that are identified as critical, applied templates **256** are created (step **424**). The creation of applied templates **256** may comprise obtaining a library template **252** from the template library **208**, and saving a copy of that library template **252** as an applied template **256** in the set of applied templates **212**. Saving a copy of a library template **252** as an applied template **256** may comprise modifying a copy of the library template **252**, at least to include a reference between the component **112** being modeled and the applied template **256**. Additional modifications may also be made to a copy of a library template **252** in creating an applied template **256**. Such additional modifications may, for example, reflect differences between the actual component **112** that is modeled by the applied template **256** or the actual critical function of that component **112** and the component represented by the library template **252**. Furthermore, an applied template **256** may be modified to include additional information related to particular aspects of the component **112**, or may be modified to exclude information related to particular aspects of the component **112** included in the library template **252**, based on the context of the system **104** that includes the component. The creation of an applied template **256** may also comprise modifying a copy of another applied template **256**. Such modification may be as simple as associating the component tag of the component **112** being modeled for the component tag included in the applied template **256** being copied, or may include additional modifications. Alternatively, where there is no library template **252** that can serve as a suitable starting point, an applied template **256** may be constructed without using a library template **252** as a starting point. Whether or not an applied template **256** is created by modifying a library template **252**, a copy of the applied template **256** may be saved as a library template **252**, for example if it is anticipated that it will be useful in connection with modeling other components **112**.

As can be appreciated from the description provided herein, the identification of a suitable library template **252** or applied template **256** for modification and use in connection with a particular component can be facilitated by the identification of symmetry groups performed at step **416**. In particular, components **112** that are included in identical trains or skids performing identical functions can generally be modeled using a template that is substantively the same. Therefore, by identifying symmetries, the step of associating a template **256** that accurately and appropriately models a component **112** can, after creating an applied template **256** for one instance of the component **112**, comprise making a copy of and/or reference to that applied template **256** for association with a corresponding component **112** in a symmetrical system **104**, train, or skid. In accordance with embodiments of the present invention, copies of an applied template **256** may be made for (or an applied template **256** may be associated with) components **112** that are symmetrical with a component **112** for which an applied template **256** is originally created automatically, based on symmetry information contained in the risk/symmetry table **218**.

After development of a complex plant **100** model through the creation of applied templates **256** for the modeled systems **104**, reports can be provided (step **428**). In general, reports are created by operation of the report generator **244**, in response to selections and/or queries made by a user. Such reports may include preventive maintenance operations and repair operations, grouped or partitioned according to functions or symmetries that have been identified and that are reflected in the model maintained by the reliability system **200**.

Prior to deploying the reliability system **200**, a review of the plant **100** model may be made (step **432**). Once finally approved, the reliability system **200** may be provided as a database file or files, in association with the administrative program **204**, and operated as a complete preventive maintenance and diagnostic repair program (step **436**).

With reference to FIG. **5**, aspects of the operation of a reliability system **200** with respect to the creation of applied templates **256** are illustrated. Initially, a template copy (i.e. a copy of an existing library template **252** or applied template **256**) is taken for editing by a user (step **504**). As an alternative, an applied template **256** can be created from scratch, in which case a copy would be saved to both the template library **208** and the set of applied templates **212** after creation.

The context in which the component **112** to be modeled by the applied template **256** being created operates is then considered (step **508**). Consideration of the context of the component **112** may comprise identifying the system **104** of which the component **112** is a part, and the function performed by the system **104** within the complex plant **100**. Through consideration of the functional requirements provided by the component **112**, the critical requirements and failures associated with the component **112** are identified.

In accordance with embodiments of the reliability system **200**, each applied template **256** must be justified in order to be included as part of an operational reliability system **200**. If it is determined at step **512** that justification is required, the user is prompted for justifications (step **516**). Justification can include requiring that a dominant failure, failure effects (direct or hidden safety, operational and cost effects), preventive maintenance tasks, and/or preventive maintenance task intervals are identified for the component **112** in the applied template **256**. Modifications or edits to the applied template **256**, for example as compared to an earlier version of the applied template **256** instance being edited, or as compared to the library template **252** or applied template **256** on which the applied template **256** instance being edited are based, may as part of justification be required to be associated with textual reasons or justifications for changes. Furthermore, the textual justifications may be associated with the person making the entry. By requiring justification for changes, regulatory compliance review is facilitated. In addition, an adaptable or living reliability system **200** is provided. Another advantage of requiring justification through operation of the reliability system **200** in connection with the creation of applied templates **256** is that justification can be required at the point of change or edit entry, while the reason for the change is fresh in the user's mind.

After justification, or after it is determined that justification is not required, the applied template **256** instance is associated with a particular component **112** within a system **104** of the complex plant **100** (step **520**). That is, the template is "applied" to an actual component. A copy of the applied template **256** is then saved to the database **328** as one of the applied templates **256** in the set of applied templates **212** (step **524**). In particular, the applied template **256** is saved with all of the historical information, including information regarding the lineage (e.g. the library **252** and or applied **256** templates on which the saved applied template **256** is based). Examples of other information that can comprise or be included with the copy of the applied template **256** includes: dominant failures of the component **112** or parts of the component **112** being modeled; the identified hidden safety, operational and cost failure effects; the preventive maintenance tasks for identified failure modes; preventive maintenance tasks for the identified context; the explicit basis inputs; the implicit function-failure-task links; the explicit contextual information; the identity of the user who has entered or made changes to the applied template **256**; the dates of changes; associations with workscopes; and associated component tags. In accordance with embodiments of the reliability system **200**, implicit information is obtained from database design relationships, while explicit information is obtained from notes or entries made in provided text fields. As the copy of the applied template **256** is saved, it may be updated with current reference and user data (step **528**). The process for creating an applied template **256** may then be continued by getting or creating a next template (step **532**).

With reference to FIG. **6**, generalized aspects of a process for creating an applied template **256** in accordance with embodiments of the present invention are illustrated. In general, templates are applied only to critical components **112**. In accordance with further embodiments of the reliability system **200**, blank library templates **252** can be provided to facilitate creating an applied template **256** that is completely customized. Accordingly, an initial step is to identify critical components **112** (step **604**). Critical components are components **112** that by failing will directly compromise the system **104** with which they are associated, or that otherwise impact the safety, operations or costs of the complex plant **100**. After identifying critical components **112**, one of those components **112** can be selected by selecting the component tag for one of the critical components (i.e. by selecting one of the identified critical components) (step **608**). A component tag serves to uniquely identify a component within a complex plant **100**.

The component type for the selected component **112** can then be identified (step **612**). The component type can assist in identifying any suitable, close or otherwise appropriate library templates **252** that might already exist, as library templates **252** are typically organized in the template library **208** by type. Examples of just a few component types that may be used in connection with organizing library templates **252** are pumps, valves, motors and switches. Having identified the component type, the template library **208** can be checked for similar component models (i.e. for library templates **252** that are similar to the selected component **112**) (step **616**). If a suitable model or library template **252** is found for the selected component **112** (step **620**), that library template can be used as the application template **256** (step **624**).

If at step **620** it is determined that a suitable model can not be found in the template library **208**, a library template **252** can be built (step **628**). Building a library template **252** can comprise either copying and editing a library template **252** (step **632**), or building the new library template **252** from scratch (step **636**).

After selecting an existing library template **252** (at step **624**), or after building a suitable library template **252** (at steps **628** and either **632** or **636**), the library template **252** can be applied (step **640**), for example as described in connection with FIG. **5**. Once applied templates **256** have been created, it is then possible to generate and provide reports (step **644**) and to provide formatted database files (step **648**).

In FIG. **7**, aspects of the operation of a reliability system **200** in connection with a completed or operating complex plant **100** are illustrated. With a scheduled maintenance plan available from the creation of a set of applied templates **256** (step **704**) and a scheduler function of the reliability system **200** or of an associated scheduled maintenance program or engine enabled and running (step **708**), a determination can be made as to whether scheduled maintenance is due (step **712**). More particularly, maintenance operations set forth for components **112** as part of applied templates **256** can be accessed by or made available to a scheduler functions or to a scheduled maintenance program for presentation to a user. If scheduled maintenance is due, a preventive maintenance work order, including electronic instructions delivered through a device such as a personal digital assistant (PDA), is generated from the applied templates **256** that serve as a model of the complex plant (step **716**). As used herein, a work order may comprise a set of maintenance procedures that are performed at or about the same time. In accordance with embodiments of the present invention, the applied templates **256** used in connection with the generation of preventive maintenance work orders are those templates stored as a locked set of application templates **228**. In accordance with still other embodiments of the present invention, the working set of applied templates **212** can be used.

At step **720** the work order is performed. Performing the work order can comprise making rounds. In addition, the condition or status of components **112** identified as part of the work order are determined or assessed as part of the check task step (step **724**). For example, checks and tests can be performed. Tests can include failure finding tasks or tests designed to uncover hidden failures. Work orders can also comprise replacing components or component parts. It is determined at step **728** that a component **112** or component **112** related status does not fail any established limits, the process may return to step **712** to determine whether any additional scheduled maintenance is due.

If it is determined at step **728** that a component **112** has failed an established limit, then maintenance directed by the detected condition is performed (i.e. condition directed maintenance is performed) (step **732**). In connection with addressing the failure, the detected failure mechanism is evaluated (step **736**). In particular, a determination may be made as to whether the detected failure represented an anticipated functional failure mode. An anticipated functional failure mode may comprise a failure mode that is documented as part of the applied template **256** corresponding to the component **112** subject to the failure. If at step **740** it is determined that the detected functional failure comprised an anticipated failure mode, the process of performing maintenance may end (or the process may return to step **712** for ongoing complex plant **100** maintenance).

If at step **740** it is determined that the detected failure represents a new or unanticipated failure mode, the new failure mechanism is evaluated (step **744**). In particular, the failure mode mechanism is evaluated to determine whether it is important or critical, for example with respect to the safety,

operations or cost objectives of the complex plant **100**. If the failure mode represents an important failure mechanism, it can be added to the templates **252** and/or **256** for the associated component **112**. For example, preventive maintenance can be specified that is directed to early detection of a condition that would lead to the failure. A corresponding change may also be made to the risk/symmetry table **218** to reflect the revisions to the templates **252** and/or **256**, and to document the rationale for the revisions to the templates **252** and/or **256**. In addition, a determination can be made as to whether a complex plant **100** or component **112** design change is needed (step **748**). For example, in view of the failure, it may be desirable to replace the failed component **112** with a substitute component **112**. If no design change is deemed necessary, the process of performing maintenance may end (or the process may return to step **712** for ongoing complex plant **100** maintenance).

If a design change is deemed necessary or desirable, the failed component **112** or larger aspects of the complex plant **100** are redesigned (step **752**). If the component **112** is redesigned (step **756**), then the library template **252** and/or the applied template **256** is modified as required so that the redesigned component **112** is modeled correctly (step **760**). If larger aspects of the complex plant are redesigned (step **764**), then a new or modified master equipment list **216** and risk/symmetry **218** tables are generated, and corresponding changes to the application templates **256** for at least the affected components are generated (step **768**). After modifying the component **112** or larger aspects of the complex plant **100**, the process may end (or the process may return to step **712** for ongoing complex plant **100** maintenance).

With reference to FIG. **8**, aspects of the modification of a reliability system **200** in response to modifications to a modeled complex plant **100** are illustrated. In particular, at step **804**, the design for the complex plant **100** is fixed or has been created, for example in its as-built or as-designed state. A maintenance plan for the complex plant **100**, as modeled by the reliability system **200** may then be created (step **808**). Accordingly, the model of the as-built or as-designed complex plant **100** may serve as a baseline. Furthermore, the baseline model of the complex plant **100** may be stored as a locked version or set of applied templates **260**.

A determination may then be made as to whether the complex plant **100** has been modified (step **812**). If no modification has been made, the plant modification process may end. If the complex plant **100** has been modified, a determination may be made as to whether a modification of the plant model within the reliability system **200** is necessary (step **816**). A modification that requires a change to the plant model can be subtle. For example, in certain contexts, such as nuclear power plants, a modification that requires a change to the plant model can include the replacement of a part with a different substitute part that has the equivalent fit, form and function of the replaced part, but that is not identical to the replaced part. In addition, a modification can be represented in the master equipment list **216** and/or the risk symmetry map **218**. If no modification of the complex plant model is necessary, the plant modification process may end.

If changes to the complex plant model are necessary, those changes can be entered as a redesign to the applied templates **256** corresponding to the redesigned components **112** or systems **104** of the complex plant **100** (step **820**). If it is determined that a redesign of a component **112** is necessary (at step **824**), then the component **112** is redesigned (step **828**), and a new or modified application template **256** for the redesigned component **112** is created (step **832**). The new or modified application template **256** is then added to the set of applied templates **212**. If it is determined that a redesign of the plant is necessary (at step **824**), then the complex plant **100** is redesigned (step **840**). A new master equipment list **216** is generated, along with new corresponding risk/symmetry information **218** (step **844**). At step **848**, the risk to safety operations and cost objectives of the complex plant **100** as a result of the redesign are redeveloped (step **848**). In addition, the application templates **256** are changed as necessary to represent the new master equipment list, and the application templates **256** are stored in the set of applied templates **212** (step **852**).

In general workscope tasks are enumerated lists that comprise complete workscopes. Workscopes may in turn make up or comprise work orders. Workscopes exist as part of library templates **252**, but only become truly relevant to a reliability system **200** when they are associated with a context as part of an applied template **256**. For example, a component in a containment area of a nuclear power plant will typically comprise tasks that are not necessary in connection with that same component in an easily accessed location. In FIG. **9**, an example process for assigning workscope tasks to workscopes is illustrated. Initially, tasks or maintenance procedures are held as unassigned tasks in an unassigned task holding space (step **904**) in general, tasks may originate from maintenance or repair procedures associated with components **112** that are represented by applied templates **256** (i.e. with respect to components **112** that are critical to the safety, operations or cost performance of the complex plant). The tasks may then be defined (step **908**). The defining of tasks generally includes developing lists of related tasks, task strategies (e.g. time based maintenance, failure finding, corrective maintenance or no scheduled maintenance (NSM)), task plans and resources to be assigned to the task. After the tasks have been defined, those tasks that are deemed appropriate for being associated with a workscope are identified (step **912**).

At step **916**, a determination is made as to whether an appropriate workscope for a task identified as needing to be assigned to a workscope already exists. If such an appropriate workscope does not already exist, a workscope appropriate for the task is made (step **920**). After making (at step **920**) or identifying (at step **916**) an appropriate workscope, the task is added to that workscope (step **924**).

In connection with adding a task to a workscope, an evaluation of the relationship of the task to the workscope is performed (step **928**). In particular, the craft associated with the task, and the trip time and tagout boundaries associated with the complete workscope are considered. At step **932**, the total resources required for the complete workscope are estimated. The required resources can comprise as assessment of the amount of time in personnel work hours, which typically depends on the time required to perform the individual task or tasks included in the workscope, time for breaks, tool pickup, and tagout time. As part of the evaluation process, documentation of the basis for the grouping of tasks comprising the workscope can be required (step **936**). Documentation of task grouping is particularly desirable in connection with complex work orders. In addition, the workscope and the task lists included in the workscope can be distributed to maintenance personnel for review (step **940**).

At step **944**, a determination can be made as to whether the workscope being evaluated requires revision. Changes to the workscope may be indicated if any of the evaluation steps **928-940** indicate that the grouping of tasks within the workscope is inappropriate. As examples, if the grouping of tasks is random, cannot be completed within a reasonable period of time, requires inefficient routing, or is not within applicable work rules, the workscope should be modified. Whether the

tasks included in a workscope are inappropriate can be determined by craft workers who would be called on to perform included tasks if the workscope was implemented. If modification is required, the process proceeds to step **948** for reassignment of the task to a different workscope, and for reevaluation of the workscope at steps **928-940**. If the workscope evaluation determines that the workscope is appropriate, the process of assigning a task to a workscope may end.

As can be appreciated by one of the skill in the art after consideration of the discussion provided herein, because workscopes are tied to applied templates **256**, workscopes and work scheduled in connection with workscopes change with changes to the master equipment list **216**, and/or changes in the identity of components **112**. Because the workscopes and scheduled work are tied to the master equipment list **216**, workscopes and scheduled work remains relevant to the complex plant **100** as it actually exists, without requiring changes to the reliability system **200**, other than changes tracking modifications to the master equipment list **216**. In addition, because workscopes apply to components **112** identified as critical, workscopes are directed to those components **112** that have an impact on safety, operations or cost. Accordingly, work performed as part of workscopes is targeted to maintaining important components, such that maintenance resources are not wasted on maintaining unimportant or non-critical components.

Embodiments of a reliability system **200** as disclosed can also provide for or assist in the identification of critical part spares to assist in maintaining an appropriate stock of spare parts. In particular, spare parts that should be kept on hand are identified with reference to the master equipment list **216**, and with reference to the consequences to the complex plant **100** if a particular component **112** should fail due to a failure of an included part.

FIG. **10** illustrates aspects of the operation of a reliability system **200** in connection with identifying spare parts that should be stocked. Initially, at step **1004**, the scope of the reliability system **200** is selected. That is, an engineering analysis of the master equipment list **216** has been completed, and critical equipment (i.e. equipment having a safety, operational or cost impact on the complex plant **100**) has been identified. In addition, applied templates **256** have been applied to the critical components **112** in the master equipment list **216**. A symmetry mapping, showing replications between components **112** in the master equipment list **216** has also been completed, and critical parts, failure modes and work order tasks are available to identify, extract and summarize, from the applied templates **256**. At step **1008**, the critical equipment or components **112** from the master equipment list **216** are identified for a system **104** under analysis. At step **1012**, components **112** that share a common applied template **256** are identified. This can comprise identifying application users from symmetries identified within the system model to obtain a total number of instances of each component **112** modeled by or represented in the reliability system **200**.

At step **1016**, each component **112** represented by an applied template **256** is analyzed to determine whether a part level safety, operations or cost criticality has been addressed with respect to the component **112** represented by the applied template **256**. That is, every critical component **112** is comprised of at least one part, and at least one part therefore is associated with a failure mode that is associated with the component **112**. If no part level criticality has been associated with the part, a part level criticality is added or assigned to the applied template **256** and, with respect to critical parts, a safety, operational or cost consideration is assigned to the part (step **1024**). This may include analyzing the probability of failure associated with the part, and the predictability of failure of the part. After assigning criticality to a part, or after determining that a part level criticality has already been assigned, the application model, as represented by the applied templates **256** is updated (step **1028**). In particular, information regarding criticality is added to an applied template **256**, or the existence of such information in the applied template **256** or the component **112** under consideration is confirmed.

In general, the process of assigning criticality to at least one part included in a critical component **112** is performed for each critical component **112** in the system **104** under consideration. Furthermore, the process of assigning a criticality to at least one part included in every critical component **112** in a system **104** is performed for each system **104** in the complex plant **100**. After at least one critical part included in each critical component **112** of each system **104** in a plant **100** has been identified, multiple instances of identical or similar critical parts are identified. In particular, multiple like parts are identified in the applied templates **256** (step **1032**). By identifying each instance of a part within a system **104** of a complex plant **100**, information related to the number of spares that should be stocked, for example at the complex plant **100** or such that the part is readily available for installation in the complex plant **100**, can be obtained. Like (i.e. repeated) parts in all applied templates **256** are then identified, and the number of instances of each repeated part is counted (step **1036**). The list of critical parts may then be cross-referenced to stock codes and grouped for risk analysis (step **1038**).

The list of stock codes for spares may also be organized for spares analysis (step **1040**). Spares analysis may include analyzing whether parts are standard or unique, the safety, operations or cost criticality of the part, the probability of failure, the lead time to procure a replacement, the time to repair, the availability to repair and other considerations affecting the benefits of keeping spares on hand. The critical component part list may be grouped according to part or type of part. The list may then be evaluated for risk (step **1044**). In particular, the risk of not stocking spares for critical parts, or of stocking spares for less than all instances of a critical part are analyzed. For instance, if a part fails randomly and infrequently, it may be determined that a replacement for each instance of that part does not need to be stocked. As a further example, for parts that fail due to aging, it may be determined that a replacement should be stocked for each instance of the part.

The risk strategy may then be assessed (step **1048**). Assessing the risk strategy can include deciding whether to stock a particular part and the number of such parts to stock, whether to join a user group that pulls stocked components among the members, or whether to not stock any spares of a particular critical component. Accordingly, assessing the risk strategy includes considerations of the consequences of a failure of a critical part, the time to procure a new part, and procurement strategies for obtaining needed parts. At step **1052**, a strategy is developed and a decision is made regarding the identity and number of critical parts to stock. The identity and number of parts to stock may be expressed in terms of stock codes. In accordance with embodiments of the present invention, the stock codes are those codes used to identify parts that have been developed in connection with a procurement system in use at the plant. As part of assigning stock codes, a determination may be made as to whether stocked parts are obtained from original equipment manufacturers (OEMs), or from other sources. Furthermore, this decision may be made in terms of risk and convenience. For example, a part supplied by an OEM can generally be assumed to meet all of the

operating requirements of the associated component **112**. However, when a part from a non-OEM supplier is used, the specifications of that part need to be considered in order to verify that it is a true equivalent to the OEM part.

At step **1056**, a determination may be made as to whether the failure risk for the spare part stocking strategy that has been developed is acceptable. If not, the various analysis steps **1032** through **1052** can be repeated. If the determined risk associated with the develop strategy is acceptable, the process of determining the parts to stock in association with a system **104** in the complex plant **100** may end. This process may be completed for each system **104** included in the complex plant **100**.

As can be appreciated by one of skill in the art after an appreciation of the description provided herein, embodiments of the present invention facilitate or allow decisions regarding parts to be stocked to be based on an analysis of what parts are critical to a complex plant **100**. Therefore, the stocking of unimportant parts is avoided. In addition, embodiments of the present invention allow identical parts within the complex plant to be identified and counted, to facilitate informed decisions regarding the number of spares to stock.

FIGS. **11-17** illustrate screen shots such as may be provided to a user by a user interface **248**, comprising the user input/output **320** of a client computer **308** running a client administrative program **316** in association with a server **304** running a server administrative program **312** in accordance with embodiments of the present invention. More particularly, the screen shot **1100** in FIG. **1** illustrates an exemplary list **1104** of generic or library templates **252** that can be selected by a user in connection with the creation of an applied template **256**. The list **1104** of library templates **252** can be filtered and sorted, to assist a user in locating a desired template **252**. The list **1104** is shown as a window **1108** that overlays template data for a selected library template **252**.

FIG. **12** is a screen shot **1200** illustrating a display of a list of the parts **1204** of a component **112** modeled by a library template **252**. In addition, for a selected part **1208**, a part failure mechanism **1212** and a part function **1216** are displayed. A user may make selections and enter or access information regarding component parts and failures using provided fields, which may be user editable.

FIG. **13** is a screen shot **1300** of an example a tree view **1304** of applied templates **256** that have been associated with a system **104**. The tree view **1304** allows a user to view parts associated with the components represented by applied templates **256**. In addition, for a selected applied template **256**, template information is displayed in a window **1308**. Information can include the state of the applied template **1312**, the generic or library template **252** on which the applied template is based **1316** and details related to the selection of the modeled component **112** as a critical component in a selection basis **1320** field.

FIG. **14** is a screen shot **1400** of a tree view **1404** that displays parts of a component modeled by a selected applied template **256**, part failure modes associated with each part, and preventive maintenance tasks associated with each part failure mode. Check boxes are provided to allow a user to select those parts, failure modes and preventive maintenance tasks that are relevant to the component **112** being modeled by the applied template **256**, in view of the context and/or system **104** in which the component **112** is associated. Accordingly, screen shot **1400** is an example of the user interface that is used in connection with the creation of an applied template **256** from a library template **252**. Furthermore, FIG. **14** illustrates that, by selecting relevant parts and failure modes, preventive maintenance tasks associated with a component, which are displayed in a non-editable preview window **1408**, can be altered. Accordingly, critical or important aspects of a particular instance of a component **112** can be entered or selected by a user quickly and conveniently. FIG. **14** also illustrates that the bases for maintenance tasks or other information related to parts of a modeled component can be entered and recorded. Therefore, regulatory, past experience or other justifications for requiring a particular task can be recorded in association with the task.

FIG. **15** is a screen shot **1500** of a window **1504** displaying preventive maintenance tasks **1508** associated with the parts of a component **112**. In addition, information related to the failure of a selected part failure **1512** can be displayed. FIG. **16** is a screen shot **1600** illustrating information that can be displayed to a user in response to the selection of a particular preventive maintenance task. This information can include a summary of the preventive maintenance tasks, and details of the task, including justification for performing the task.

FIG. **17** is a screen shot **1700** illustrating a display that may be provided to a user in response to the selection of a particular workscope. In particular, a list of preventive maintenance tasks **1704** comprising the workscope can be presented to the user. Drop down lists can also be accessed through the list of preventive maintenance tasks **1704**, to access details regarding aspects of the task, or the associated part.

FIG. **18** is a screen shot **1800** illustrating a display that may be provided to a user in response to the selection of a particular component template **256**. In particular, a list of critical parts comprising the represented component is displayed in a tree view. Moreover, the critical parts may be associated with failure modes or conditions, and maintenance procedures that can be performed in connection with the indicated conditions. In accordance with embodiments of the present invention, the failure risk associated with each of the listed parts is color-coded. For example, red items **1804** indicate that failure of the associated part presents a safety risks. Parts and failure modes indicated in blue **1808** represent an operational risk. Parts and failure modes represented in green **1812** present a cost risk. The use of black text **1816** indicates that a condition represents no risk or a minor risk. In general, parts themselves will not be represented in black, as usually only critical parts (i.e., parts that are associated with a safety, operational or cost risk) are included in a component template **256**.

FIG. **19** is a screen shot **1900** illustrating a display that may be provided to a user regarding component function impacts. For example, specific function failures and the parts of a component associated with such failures may be listed in a first section or window **1904**. Separately, a listing of parts included in the selected component and a part failures list **1908** may be provided, together with the effects of particular part failures **1912**.

In FIG. **20**, a screen shot **2000** illustrating a work order scope displayed in response to the selection of a failure condition associated with a component or component part. The work order scope may include the number of hours **2004** that performance of the included work can be expected to require to complete. In addition, a listing of parts **2008** associated part failures **2012** and preventive maintenance tasks **2016** can be displayed, together with the resource or maintenance personnel specialty **2020** and time **2024** for each of the individual preventive maintenance tasks **2016**. Accordingly, the overall work scope can be divided into a member of preventive maintenance tasks that can be assigned to maintenance personnel individually.

FIG. **21** is a screen shot of user-selected parts, part failures and preventive maintenance tasks. In addition, the screen **2100** allows the user to enter the preventive maintenance

basis input authority for each part, failure and preventive maintenance task set. Examples of bases for preventive maintenance tasks include regulations, craft experience and manufacturer recommendations.

FIGS. **22**A-**22**L illustrate information that may be included in a library template **252** associated with a component comprising a low-voltage breaker. As can be appreciated by one of skill in the art after consideration of the present disclosure, the information included in the library template **252** may be reduced upon application of the library template **252** as an applied template **256** by determining that particular failures are non-critical based on the particular context of the component being modeled. Additional information may also be included with an applied template **256**, for example where additional tasks are required, for instance in order to access failed component parts, for example due to the context of the component being modeled. Other examples of library templates **252** are illustrated in FIGS. **23**A-**23**I, and FIGS. **24**A-**24**H.

The foregoing discussion of the invention has been presented for purposes of illustration and description. Further, the description is not intended to limit the invention to the form disclosed herein. Consequently, variations and modifications commensurate with the above teachings, within the skill and knowledge of the relevant art, are within the scope of the present invention. The embodiments described hereinabove are further intended to explain the best mode presently known of practicing the invention and to enable others skilled in the art to utilize the invention in such or in other embodiments and with the various modifications required by their particular application or use of the invention. It is intended that the appended claims be construed to include alternative embodiments to the extent permitted by the prior art.

What is claimed is:

1. A computer implemented method for creating a taxonomy of complex plants, comprising:

identifying at least first and second systems included in a plant;

characterizing a function of said first system with respect to said plant;

characterizing at least a first failure mode of said first system;

identifying a number of components included in said first system;

assigning a first context to at least some of said components identified in said first system, wherein said first context is related to said at least a first failure mode of said first system;

representing a first component included in said first system using a first application template, wherein said first component is assigned said first context, and wherein said first application template is derived from a first library template;

characterizing a function of said second system with respect to said plant;

characterizing at least a first failure mode of said second system;

identifying a number of components included in said second system;

assigning a second context to at least some of said components identified in said second system, wherein said second context is related to said at least a first failure mode of said second system;

representing a second component included in said second system using a second application template, wherein said second application template is derived from said first library template;

wherein said first and second application templates are different from one another, and wherein said differences are a result of at least one of: 1) differences between said first and second components; and 2) differences between said first context assigned to at least some of said components identified in said first system and said second context assigned to at least some of said components identified in said second system;

determining a response to a first failure condition of said first component assigned said first context;

determining a response to a first failure condition of said second component assigned said second context, wherein a response to a failure of an instance of said first component included in said first system and assigned said first context is different than a response to a failure of an instance of said second component included in said second system and assigned said second context;

producing an output comprising information included in said first and second application templates, wherein said output includes a human readable representation of at least a portion of said first application template and a human readable representation of at least a portion of said second application template;

replacing said first component included in said first system with a first replacement component, wherein said first replacement component is a functional equivalent of said first component, and wherein said first component and said first replacement component differ in at least one respect; and

in response to said replacing said first component with said first replacement component, revising said first application template to represent said first replacement component, wherein said revising said first application template includes revising said response to a failure of said component represented by said first application template, wherein said revising is performed to reflect said difference in at least one respect between said first component and said first replacement component.

2. The method of claim **1**, further comprising:

documenting a reason for said revising a response to a failure of said first component.

3. The method of claim **1**, wherein said method is stored as instructions on a computer readable storage medium.

4. The method of claim **1**, further comprising:

determining a criticality rank of each of said systems included in said plant, wherein said first system has a higher determined criticality rank than a criticality rank of said second system, said method further comprising:

in response to detecting a failure of said first component included in said first system and in response to detecting a failure of a second component included in said second system, scheduling servicing of said first and second components, wherein said first component is scheduled to be serviced before said second component, wherein the first and second components are the same, and wherein the difference in scheduling servicing is a result of a difference between the criticality of the first system and the criticality of the second system.

5. The method of claim **4**, wherein said determining a criticality of said systems comprises determining at least one of safety, production, operations or cost effects of a failure of each of said systems.

6. The method of claim **5**, wherein said first system is critical to safety and is ranked more critical than said second

system that is critical to production operations, and wherein said second of said systems is critical to production operations and is ranked more critical than a third system that is critical to cost effective operations.

7. The method of claim **1**, further comprising:

storing said first and second application templates, wherein said first and second components are critical components, and wherein a template is not stored for a third component that is not identified as critical to any one of said at least first and second systems.

8. The method of claim **1**, further comprising:

identifying at least a first critical part included in said first critical component;

updating said first application template to include information related to said first critical part, wherein an updated first application template is created;

storing said updated first application template;

identifying each instance of said first critical part in each of said at least first and second systems included in said plant.

9. The method of claim **1**, further comprising:

identifying at least a first critical part included in said first critical component;

identifying each instance of said first critical part in each of said at least first and second systems included in said plant.

10. The method of claim **9**, further comprising:

determining a number of spares of said first critical part to stock.

11. The method of claim **10**, further comprising:

stocking at least said determined number of spares of said first critical part in inventory.

12. The method of claim **1**, wherein said first and second components are the same and are interchangeable, but differ in that said first component is included in said first system and is assigned said first context and said second component is included in said second system and is assigned said second context.

13. The method of claim **1**, further comprising:

detecting a failure of said first component, wherein said failure comprises said first failure condition of said first component;

generating a work order, wherein said generating a work order includes outputting instructions setting forth said response to said first failure condition of said first component;

performing procedures comprising a physical implementation of said response to said first failure condition of said first component.

14. The method of claim **1**, further comprising generating a preventive maintenance operation report, outputting a preventive maintenance work order.

15. The method of claim **14**, further comprising:

performing the work order, wherein performing the work order includes replacing said first component or a part included in said first component.

16. The method of claim **14**, further comprising:

performing tests enumerated in said work order.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,627,388 B2
APPLICATION NO. : 11/461316
DATED : December 1, 2009
INVENTOR(S) : August et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

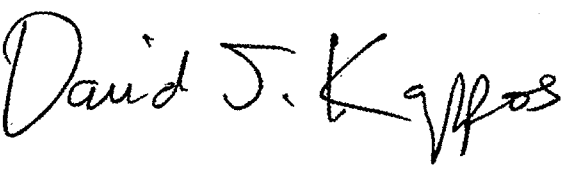
On the Title Page:

The first or sole Notice should read --

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 264 days.

Signed and Sealed this

Second Day of November, 2010



David J. Kappos
Director of the United States Patent and Trademark Office